5.4.3 Earthquake

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of climate change) and vulnerability assessment for the earthquake hazard in Morris County.

2015 Plan Update Changes

- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, probability of future occurrence, and potential change in climate and its impacts on the earthquake hazard is discussed. The earthquake hazard is now located in Section 5 of the plan update.
- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2010 and 2014.
- A vulnerability assessment was conducted for the earthquake hazard and it now directly follows the hazard profile.

5.4.3.1 Profile

Hazard Description

An earthquake is the sudden movement of the Earth's surface caused by the release of stress accumulated within or along the edge of the Earth's tectonic plates, a volcanic eruption, or by a manmade explosion (Federal Emergency Management Agency [FEMA] 2001; Shedlock and Pakiser 1997). Most earthquakes occur at the boundaries where the Earth's tectonic plates meet (faults); less than 10% of earthquakes occur within plate interiors. New Jersey is in an area where the rarer plate interior-related earthquakes occur. As plates continue to move and plate boundaries change geologically over time, weakened boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust (Shedlock and Pakiser 1997).

According to the U.S. Geological Society (USGS) Earthquake Hazards Program, an earthquake hazard is any disruption associated with an earthquake that may affect residents' normal activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches; each of these terms is defined below:

- *Surface faulting*: Displacement that reaches the earth's surface during a slip along a fault. Commonly occurs with shallow earthquakes—those with an epicenter less than 20 kilometers.
- *Ground motion (shaking):* The movement of the earth's surface from earthquakes or explosions. Ground motion or shaking is produced by waves that are generated by a sudden slip on a fault or sudden pressure at the explosive source and travel through the Earth and along its surface.
- *Landslide*: A movement of surface material down a slope.
- *Liquefaction*: A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like the wet sand near the water at the beach. Earthquake shaking can cause this effect. Liquefaction susceptibility is determined by the geological history, depositional setting, and topographic position of the soil (Stanford 2003). Liquefaction effects may occur along the shorelines of the ocean, rivers, and lakes and they can also happen in low-lying areas away from water bodies in locations where the ground water is near the earth's surface.
- *Tectonic Deformation*: A change in the original shape of a material caused by stress and strain.
- *Tsunami*: A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major sub-marine slides, or exploding volcanic islands.

- *Seiche*: The sloshing of a closed body of water, such as a lake or bay, from earthquake shaking (USGS 2012a).

Location

Earthquakes are most likely to occur in the northern parts of New Jersey, which includes Morris County, where significant faults are concentrated; however, low-magnitude events can and do occur in many other areas of the State. The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications defined by their shear-wave velocity that impact the severity of an earthquake. The soil classification system ranges from A to E, as noted in Table 5.4.3-1, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses.

Table 5.4.3-1. NEHRP Soil Classifications

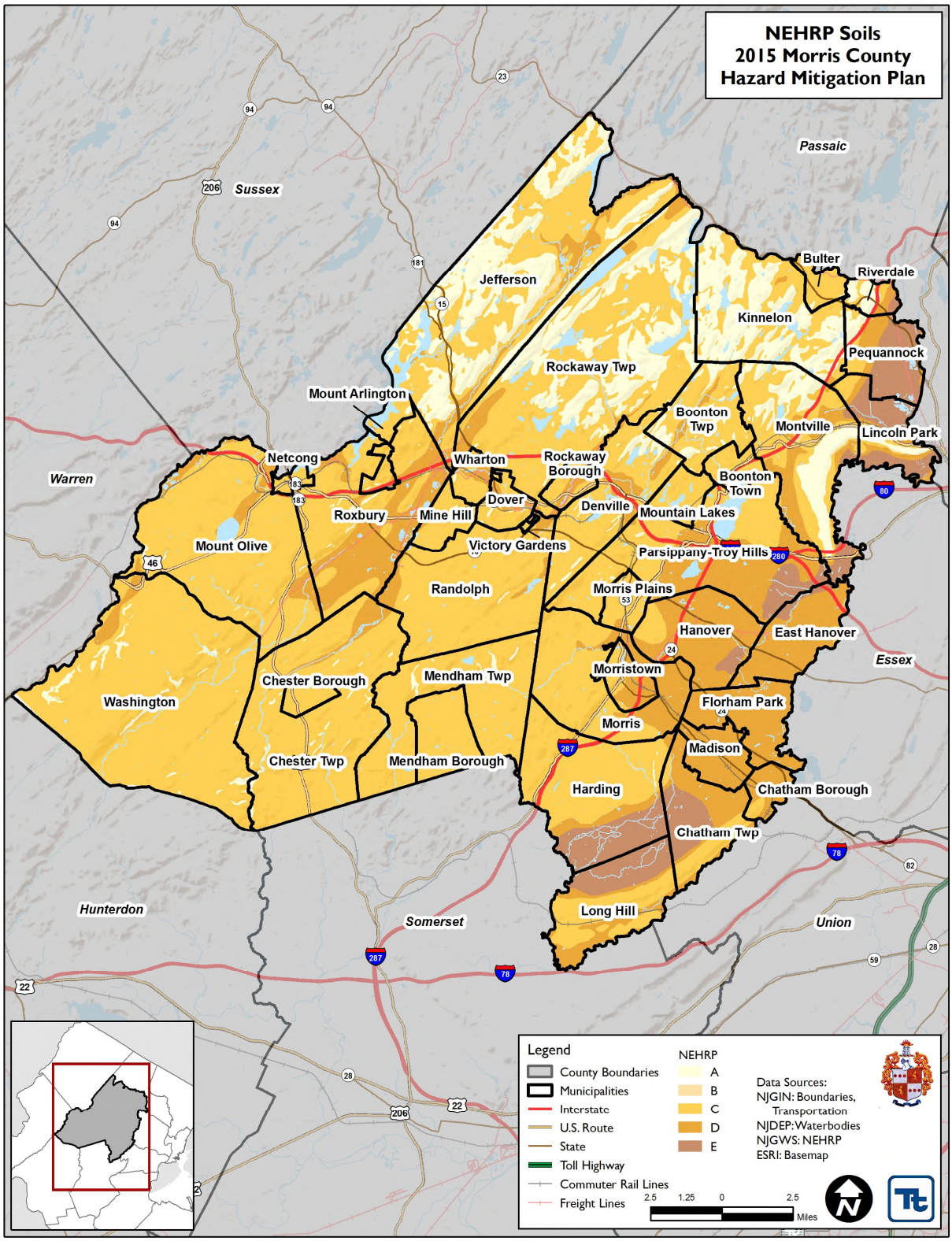
Soil Classification	Description
A	Hard Rock
B	Rock
C	Very dense soil and soft rock
D	Stiff soils
E	Soft soils

Source: FEMA 2013

Figure 5.4.3-1 illustrates the NEHRP soils located throughout Morris County. The data was available from the NJGWS. The available NEHRP soils information is incorporated into the HAZUS-MH earthquake model for the risk assessment (discussed in further detail later in this section). According to this figure, Morris County is predominately underlain by Class C soils (very dense soil and soft rock) with large bands of Class D (stiff soil) throughout the County and areas of Class A (hard rock) in the northern section of the County and Class E (soft soil) in the northeastern and southeastern corners.

Class E soils include water-saturated mud and artificial fill. The strongest amplification of shaking due is expected for this soil type. Seismic waves travel faster through hard rock than through softer rock and sediments. As the waves pass from harder to softer rocks, the waves slow down and their amplitude increases. Shaking tends to be stronger at locations with softer surface layers where seismic waves move more slowly. Ground motion above an unconsolidated landfill or soft soils can be more than 10 times stronger than at neighboring locations on rock for small ground motions (FEMA 2014).

Figure 5.4.3-1. Seismic (NEHRP) Soils in Morris County



Source: NJGWS, 2013

Liquefaction has been responsible for tremendous amounts of damage in historical earthquakes around the world. Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position. This was done in Morris County by the NJGWS. Soils were classed into the HAZUS categories using Standard Penetration Test (SPT) data, which were acquired during the drilling of test borings. SPT tests report the number of blows of a 140-pound hammer falling 30 inches that are required to drive a sampling tube 12 inches into the test material. In Morris County, data on 3,521 SPT tests from 496 borings were obtained from test boring logs on file at the NJGWS and the NJDEP, Bureau of Water Allocation. SPT data from the Morris County borings yield means, ranges, and standard deviations that are similar those from Hudson, Essex, Union, and Bergen data for the same soil types.

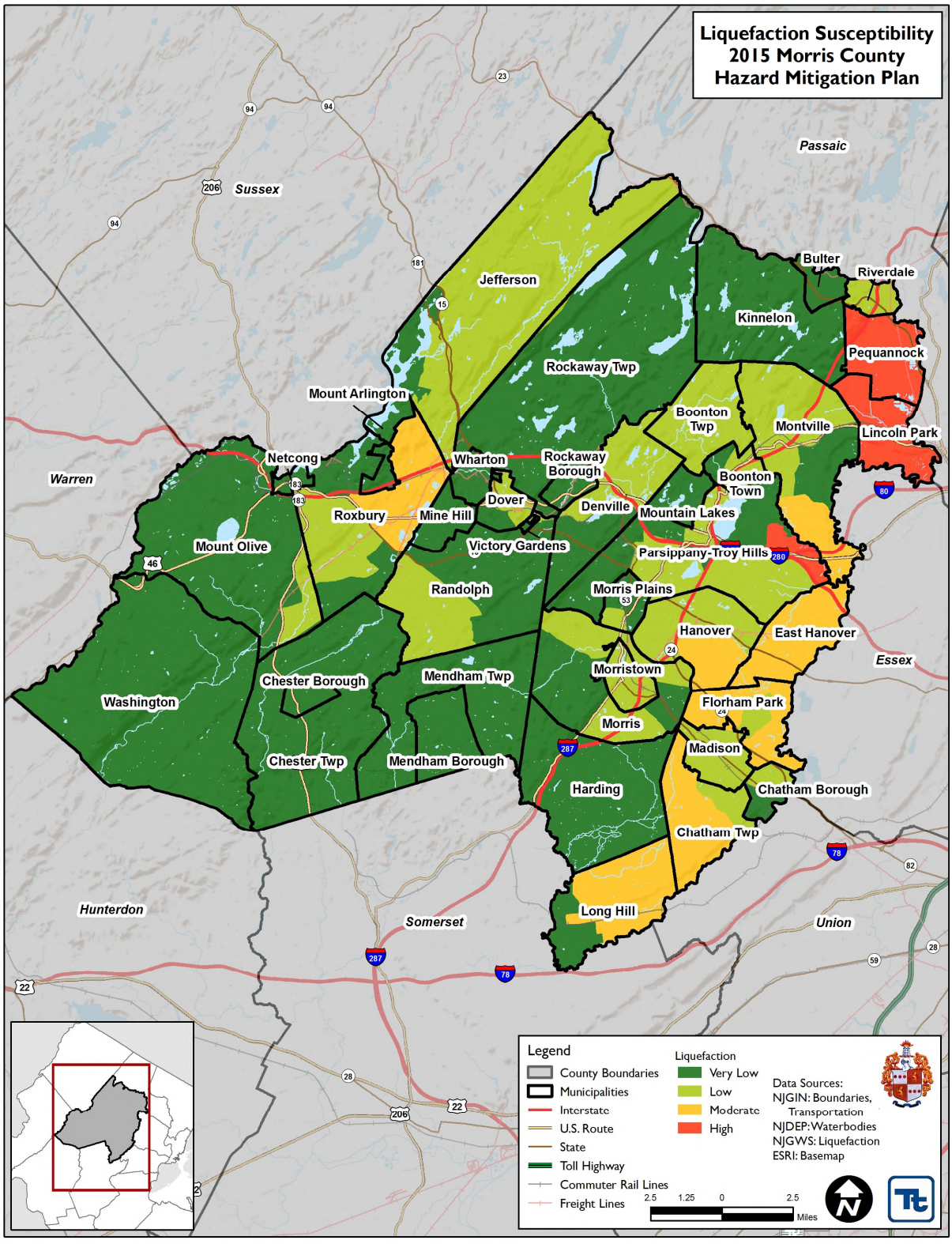
Liquefaction occurs in saturated soils and when it occurs, the strength of the soil decreases and the ability of a soil deposit to support foundations for buildings and bridges is reduced. Shaking from earthquakes often triggers an increase in water pressure which can trigger landslides and the collapse of dams. For information regarding dam failures, refer to Section 5.4.1 (Dam Failure) and for landslides refer to Section 5.4.6 (Geological Hazards).

Figure 5.4.3-2 illustrates the liquefaction susceptibility for Morris County. The classification categories are from the *HAZUS User's Manual, Table 9.1*. The coverage shows the liquefaction susceptibility of natural soils. Man-made fill overlies these soils, particularly those in Category 4, in some areas. Typically, fill has a low liquefaction susceptibility, uncompacted sand, and silt fills may liquefy. The behavior or fill during seismic shaking should be addressed on a site-specific basis. The categories are as follows:

- Category 1 – Very Low
- Category 2 – Low
- Category 3 – Moderate
- Category 4 – High

As shown in Figure 5.4.3-2, liquefaction susceptibility varies throughout Morris County. The Township of Pequannock and Borough of Lincoln Park are shown has having a high liquefaction susceptibility. The southeast portion of the Town of Boonton also has high liquefaction susceptibility. The southeastern portion of Morris County is identified as having a moderate susceptibility and the majority of the remainder of the County has a very low to low liquefaction susceptibility.

Figure 5.4.3-2. Liquefaction Classes in Morris County



Source: NJGWS, 2013

Landslides include a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. However, gravity acting on a steep slope is the primary reason for all landslides. For detailed information regarding landslides and other geological hazards, see Section 5.4.6 (Geological Hazards). Other contributing factors include:

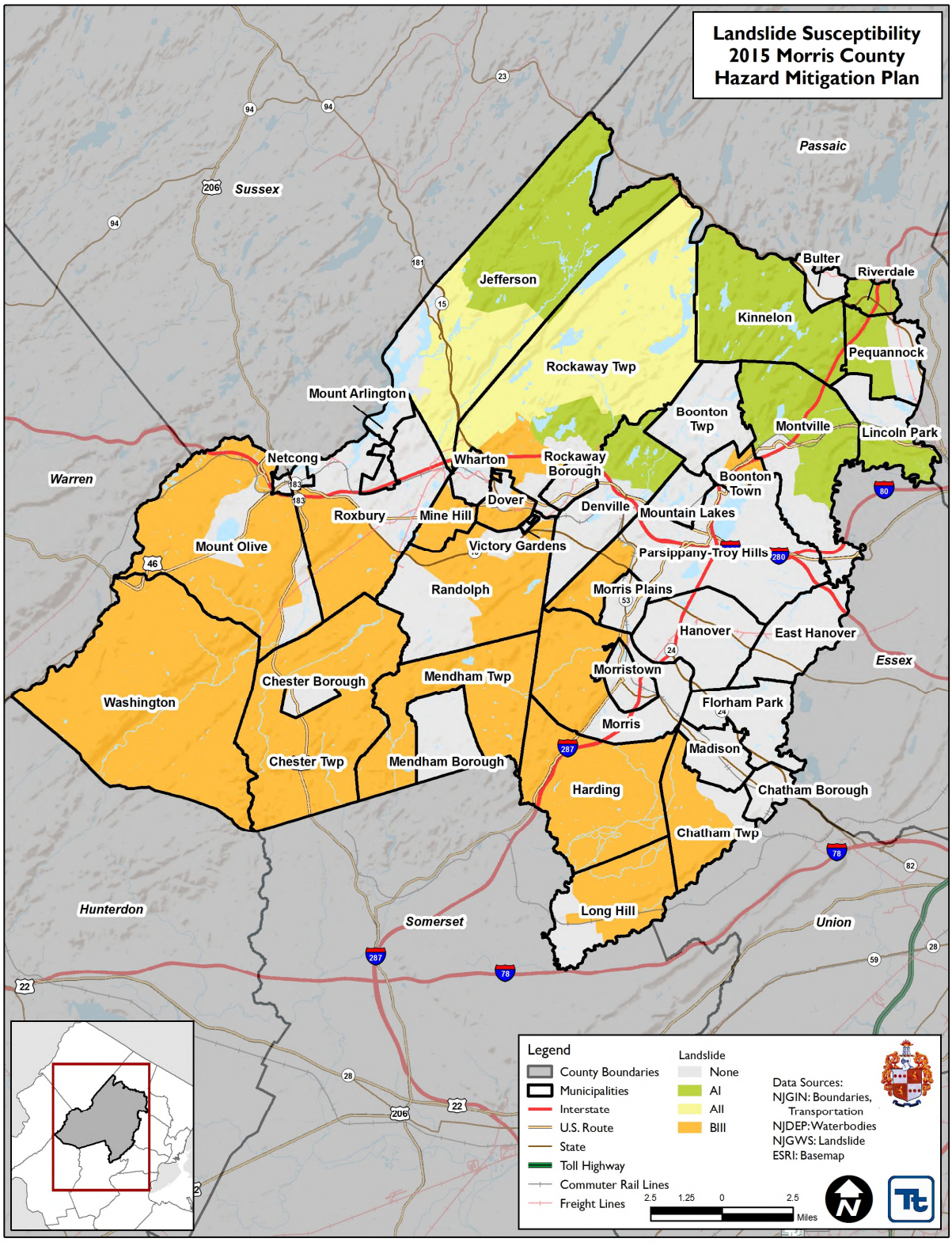
- Erosion by rivers, glaciers, or ocean waves that create oversteepened slopes
- Rock and soil slopes are weakened through saturation by snowmelt or heavy rain
- Excess weight from accumulation of rain or snow, stockpiling of rock or ore, from waste piles, or from man-made structures may stress weak slopes to failure and other structures.

Earthquakes and volcanoes also contribute to landslide hazards. Earthquakes create stresses that make weak slopes fail. Earthquakes of magnitude 4.0 or greater have been known to trigger landslides. Volcanic eruptions produce loose ash deposits, heavy rain, and debris flows. The susceptibility of slopes to landsliding during earthquakes is illustrated in Figure 5.4.3-3. The classes shown in this figure were based on the angle of the slop, the type of geological material forming the slope, and groundwater level. Slope angles were measured from the USGS 7.5-minute topographic quadrangles with 10- or 20-foot contour interval. Geological materials were determined from published and unpublished geological maps and well log data. The classes are as follows:

- None—HAZUS number 0
- Class AI—Strongly cemented rock, slope angle 15-20 degrees
- Class AII—Strongly cemented rock, slope angle 20-30 degrees
- Class AIV—Strongly cemented rock, slope angle 30-40 degrees
- Class AVI—Strongly cemented rock, slope angle >40 degrees
- Class BIII—Weakly cemented rock and sandy soil, slope angle 10-15 degrees
- Class BIV—Weakly cemented rock and sandy soil, slope angle 15-20 degrees
- Class BV— Weakly cemented rock and sandy soil, slope angle 20-30 degrees
- Class CVI—Shales and clayey soil, slope angle 10-15 degrees
- Class CVII—Shales and clayey soil, slope angle 15-20 degrees
- Class CIX—Shales and clayey soil, slope angle 20-40 degrees if dry, 10-15 degrees if groundwater at surface
- Class CX—Shales and clayey soil, groundwater at surface, slope angle >15 degrees

Figure 5.4.3-3 indicates that a majority of Morris County is classified as none, AI, AII, and BIII. The northern half of the County is a combination of Class AI, AII and no classification. Southern Morris County is classified mainly BIII.

Figure 5.4.3-3. Susceptibility of Slopes to Landsliding During Earthquakes in Morris County

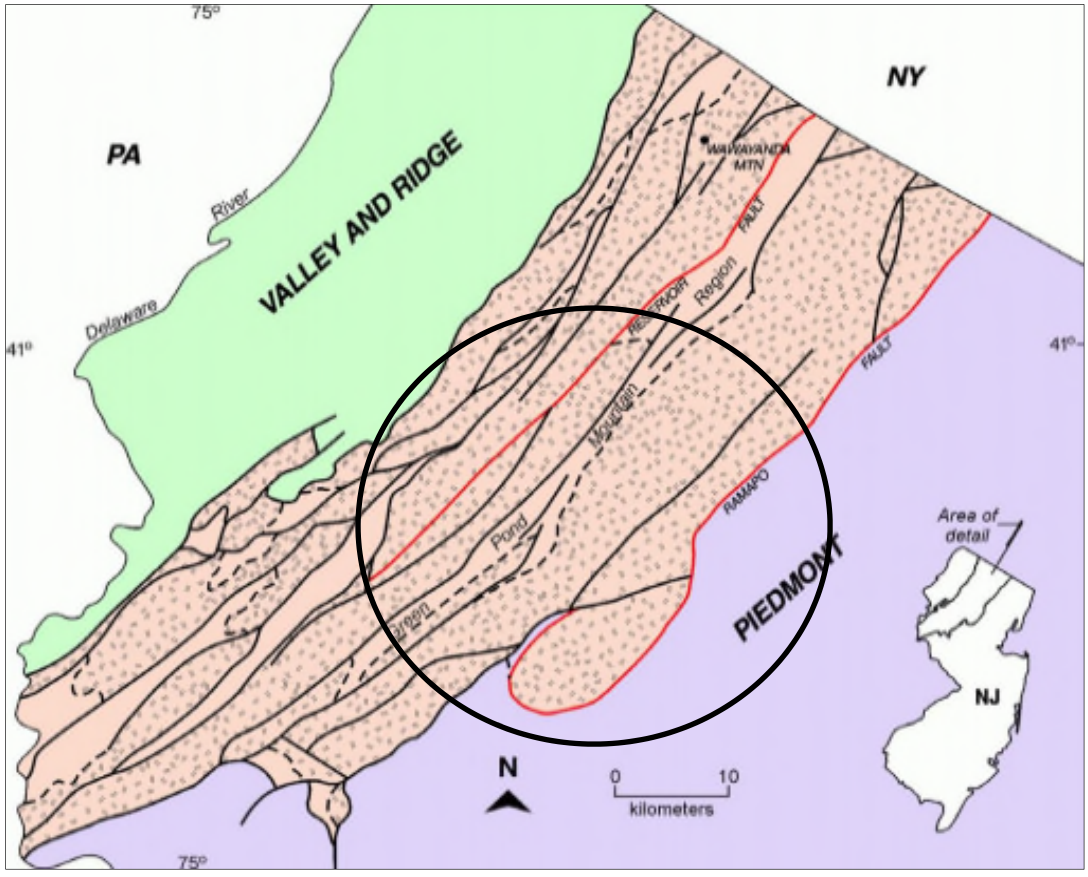


Source: NJGWS, 2013

Fractures or fracture zones along with rocks on adjacent sides have broken and moved upward, downward, or horizontally are known as faults (Volkert and Witte 2015). Movement can take place at faults and cause an earthquake. Morris County is located in the proximity of two major New Jersey fault lines: the Ramapo Fault Line and the Reservoir Fault. A majority of earthquakes that had epicenters in and around Morris County have occurred along the faults in the central and eastern New Jersey Highlands, which are further described below.

The New Jersey Highlands are a physiographic province in northern New Jersey and spans approximately 1,000 square miles of scenic and rugged terrain, which includes portions of Morris County. Faults are a common feature in the Precambrian rocks of the Highlands. The faults range in width from a few tenths of an inch to hundreds of feet and in length from a few feet to as much as tens of miles. The Ramapo fault forms the boundary between the Highlands and Piedmont Provinces. It is a major structural feature, having a width of at least several hundred feet and stretching for a length of 50 miles from Somerset County northeast into New York State. It is the most seismically active fault in the region. The Reservoir fault borders the Green Pond Mountain Region. (Volkert and Witte 2015). Figure 5.4.3-4 illustrates the location of both faults in northern New Jersey and their relation to Morris County.

Figure 5.4.3-4. Faults in Northern New Jersey



Source: *Volkert and Witte 2015*
Note (1): *This is a simplified geologic map of northern New Jersey showing the location of the Highlands (tan). Solid black lines are faults and red lines mark the Reservoir and Ramapo fault lines. Short-dashed lines mark contacts between older Precambrian rocks and younger Paleozoic rocks.*
Note (2): *The black circle indicates the approximate location of Morris County.*

Extent

An earthquake's magnitude and intensity are used to describe the size and severity of the event. Magnitude describes the size at the focus of an earthquake and intensity describes the overall felt severity of shaking during the event. The earthquake's magnitude is a measure of the energy released at the source of the earthquake and is expressed by ratings on the Richter scale and/or the moment magnitude scale. The Richter Scale measures magnitude of earthquakes and has no upper limit; however, it is not used to express damage (USGS 2014). Table 5.4.3-2 presents the Richter scale magnitudes and corresponding earthquake effects. The moment magnitude scale (MMS) is used to describe the size of an earthquake. It is based on the seismic moment and is applicable to all sizes of earthquakes (USGS 2012). The Richter Scale is not commonly used anymore, as it has been replaced by the MMS which is a more accurate measure of the earthquake size (USGS 2014). The MMS is described below.

Table 5.4.3-2. Richter Magnitude Scale

Richter Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 to 5.4	Often felt, but causes only minor damage
5.5 to 6.0	Slight damage to buildings and other structures
6.1 to 6.9	May cause a lot of damage in very populated areas
7.0 to 7.9	Major earthquake; serious damage
8.0 or greater	Great earthquake; can totally destroy communities near the epicenter

Source: Michigan Tech University Date Unknown

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. The Modified Mercalli (MMI) scale expresses intensity of an earthquake and describes how strong a shock was felt at a particular location in values. Table 5.4.3-3 summarizes earthquake intensity as expressed by the Modified Mercalli scale. Table 5.4.3-4 displays the MMI scale and its relationship to the areas peak ground acceleration.

Table 5.4.3-3. Modified Mercalli Intensity Scale

Mercalli Intensity	Shaking	Description
I	Not Felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very Strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

Table 5.4.3-3. Modified Mercalli Intensity Scale

Mercalli Intensity	Shaking	Description
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Source: USGS 2014

Table 5.4.3-4. Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< .17	Not Felt	None
II	.17 – 1.4	Weak	None
III	.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65-124	Violent	Heavy
X	>124	Extreme	Very Heavy

Source: Freeman et al. (Purdue University) 2004
Note: PGA Peak Ground Acceleration

Most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking. Modern intensity scales use terms that can be physically measured with seismometers, such as the acceleration, velocity, or displacements (movement) of the ground. The most common physical measure is peak ground acceleration (PGA). PGA is one of the most important measures used to quantify ground motion. PGA is a good index of hazard to buildings because there is a strong correlation between it and the damage a building might experience (NYCEM 2003).

PGA expresses the severity of an earthquake and is a measure of how hard the earth shakes, or accelerates, in a given geographic area. PGA is expressed as a percent acceleration force of gravity (%g). For example, 1.0%g PGA in an earthquake (an extremely strong ground motion) means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10%g PGA means that the ground acceleration is 10% that of gravity (NJOEM 2011). Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 5.4.3-5.

Table 5.4.3-5. Damage Levels Experienced in Earthquakes

Ground Motion Percentage	Explanation of Damages
1-2%g	Motions are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.

Table 5.4.3-5. Damage Levels Experienced in Earthquakes

Ground Motion Percentage	Explanation of Damages
Below 10%g	Usually causes only slight damage, except in unusually vulnerable facilities.
10 - 20%g	May cause minor-to-moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse.
20 - 50%g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
≥50%g	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

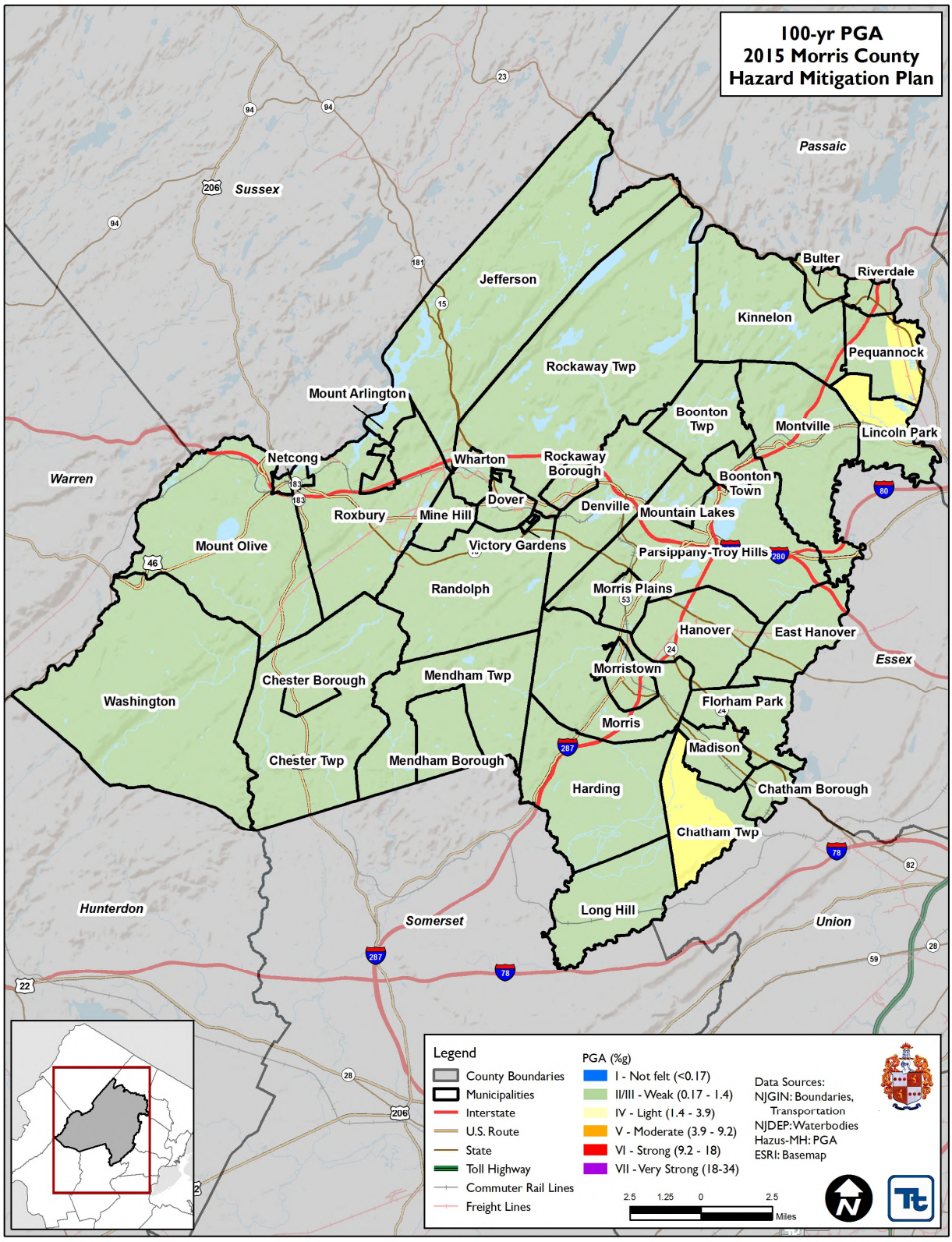
Source: NJOEM 2011
Note: %g Peak Ground Acceleration

National maps of earthquake shaking hazards have been produced since 1948. They provide information essential to creating and updating the seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities and land use planning used in the U.S. Scientists frequently revise these maps to reflect new information and knowledge. Buildings, bridges, highways and utilities built to meet modern seismic design requirements are typically able to withstand earthquakes better, with less damages and disruption. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes (Brown et al., 2001).

The USGS updated the National Seismic Hazard Maps in 2014, which superceded the 2008 maps. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps. The 2014 map represents the best available data as determined by the USGS. According to the data, Morris County has a PGA between 3%g and 5%g. (Petersen, et. al. 2014). The 2014 PGA map can be found at http://pubs.usgs.gov/of/2014/1091/pdf/ofr2014-1091.pdf.

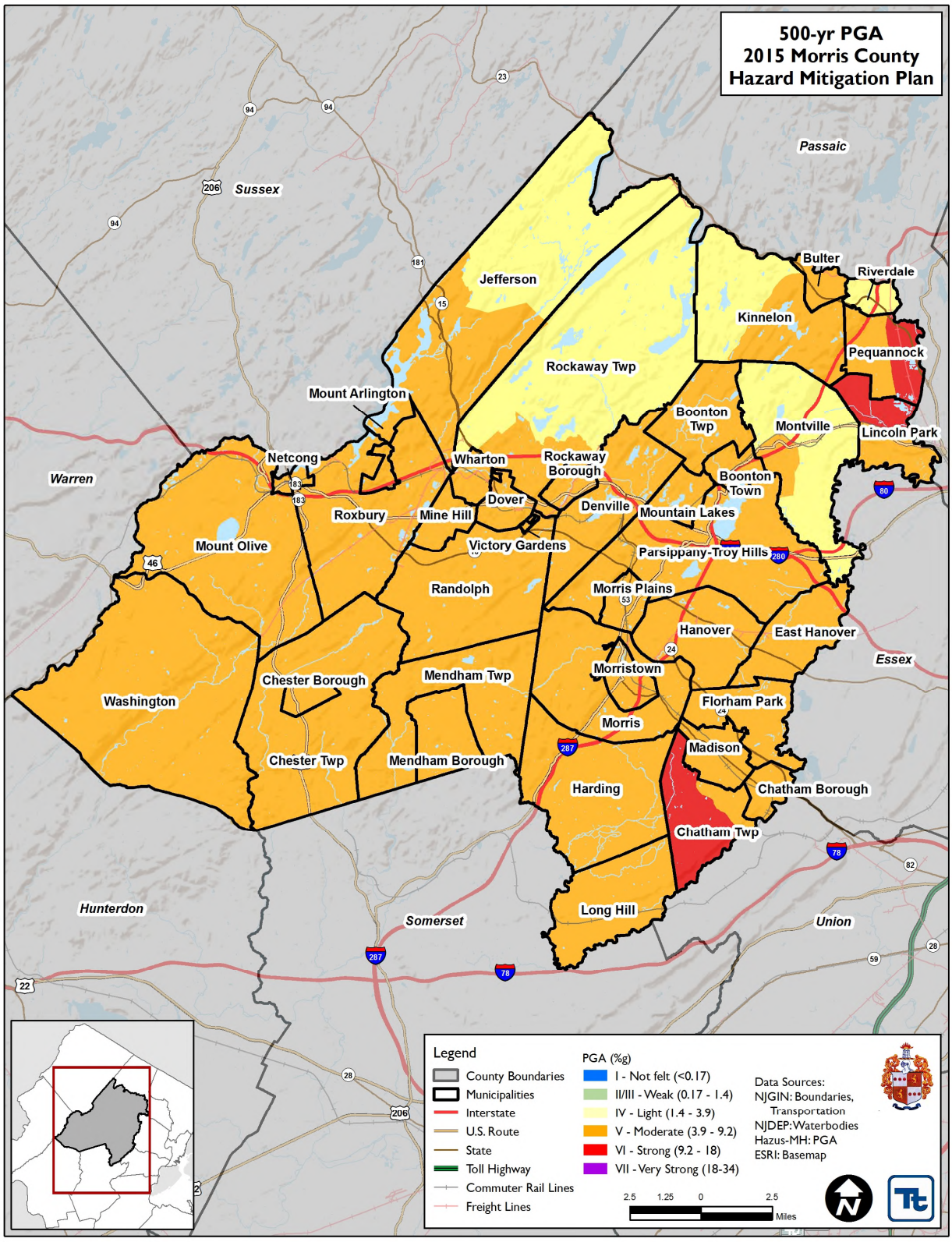
A probabilistic assessment was conducted for the 100-, 500- and 2,500-year mean return periods (MRP) in HAZUS-MH 2.1 to analyze the earthquake hazard for Morris County. The HAZUS analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. Figure 5.4.3-5 through Figure 5.4.3-7 illustrates the geographic distribution of PGA (*g*) across the County or 100-, 500- and 2,500-year MRP events by Census-tract.

Figure 5.4.3-5. Peak Ground Acceleration 100-Year Mean Return Period for Morris County



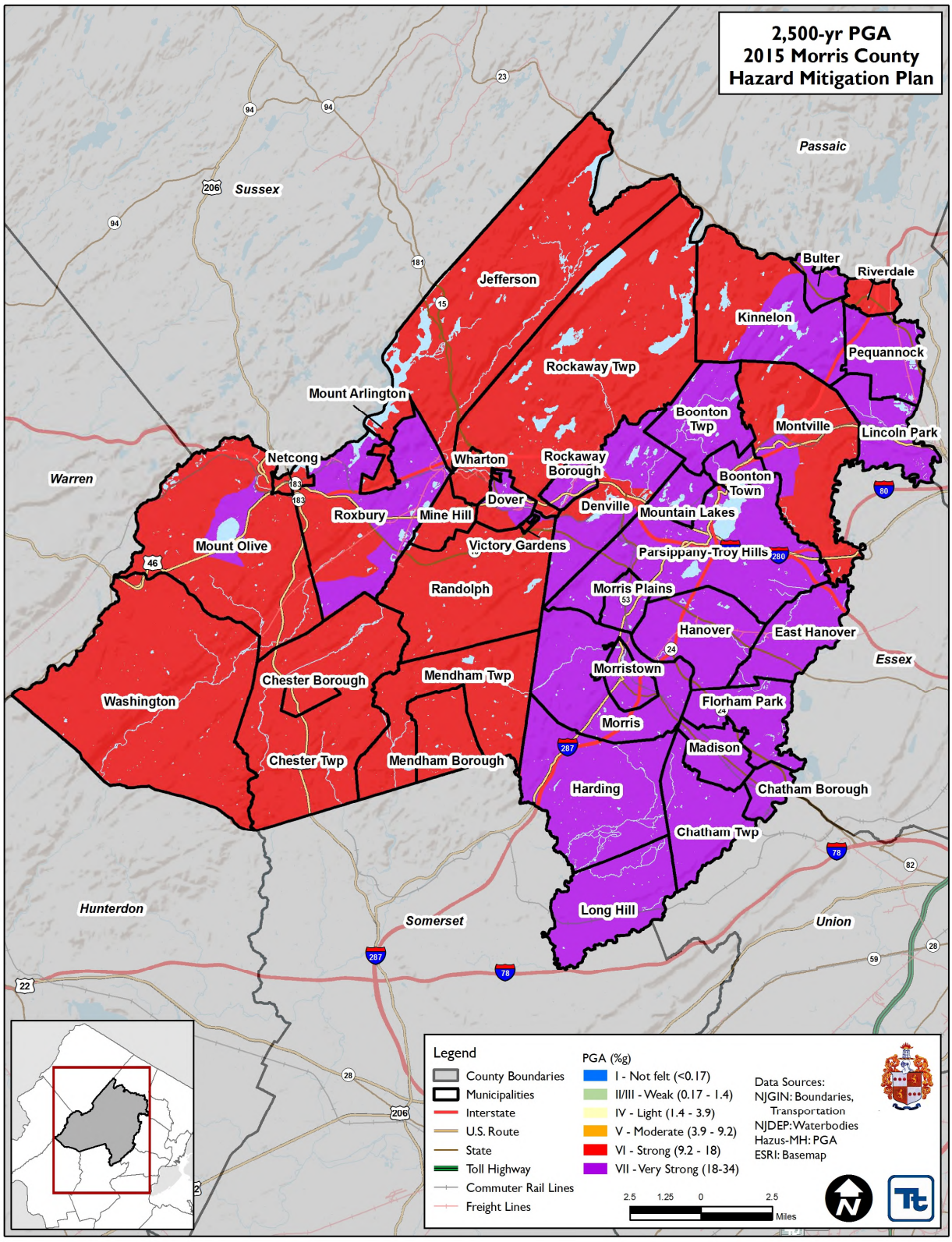
Source: HAZUS-MH 2.1

Figure 5.4.3-6. Peak Ground Acceleration 500-Year Mean Return Period for Morris County



Source: HAZUS-MH 2.1

Figure 5.4.3-7. Peak Ground Acceleration 2,500-Year Mean Return Period for Morris County



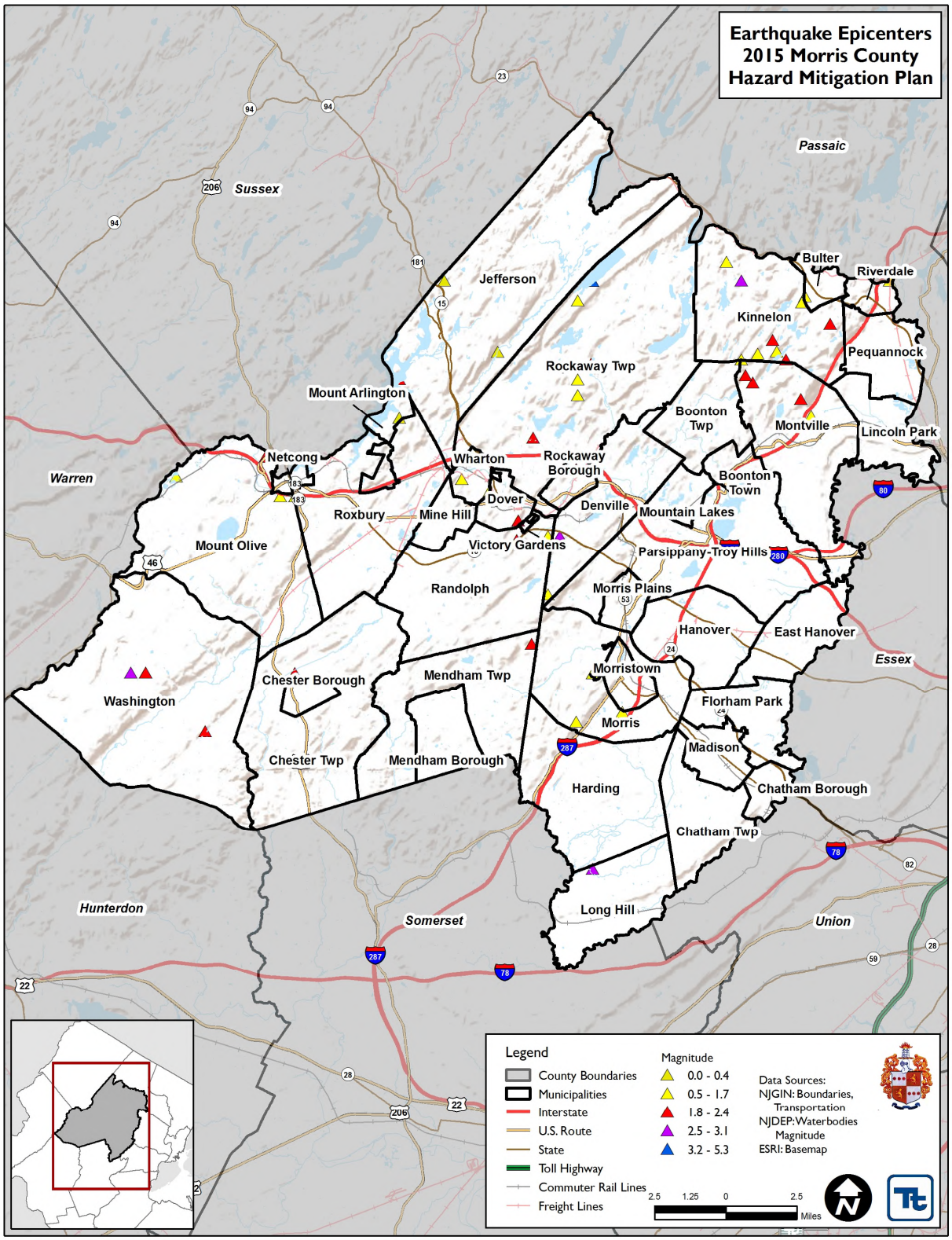
Source: HAZUS-MH 2.1

Previous Occurrences and Losses

Historically, New Jersey and Morris County have not experienced a major earthquake. However, there have been a number of earthquakes of relatively low intensity. The majority of earthquakes that have occurred in New Jersey have occurred along faults in the central and eastern Highlands, with the Ramapo fault being the most seismically active fault in the region (Volkert and Witte 2015), which includes Morris County. Small earthquakes occur several times a year and generally do not cause significant damage. The largest earthquake with its epicenter in Morris County was a magnitude 5.3 quake that was west of New York City. It was felt from New Hampshire to Pennsylvania (Stover and Coffman 1993; NJGWS 2014).

For this 2015 Plan Update, known earthquake events that have impacted Morris County or that have had its epicenter in the County, between 2008 and 2014 are identified in Appendix G. The State of New Jersey has not been included in any FEMA major disaster (DR) or emergency (EM) declarations for earthquake events. For events that occurred prior to 2008, see the 2010 Morris County HMP. Please note that not all events that have occurred in Morris County are included due to the extent of documentation and the fact that not all sources may have been identified or researched. Loss and impact information could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP Update. Figure 5.4.3-8 illustrates earthquake events where the epicenters were located in Morris. The figure shows that 13 earthquakes had epicenters in the County.

Figure 5.4.3-8. Earthquakes with Epicenters in Morris County, 1783 to 2014



Source: NJDEP 2014

Probability of Future Occurrences

Earthquakes cannot be predicted and may occur any time of the day or year. The probability of damaging earthquakes affecting Morris County is low. However, there is a definite threat of major earthquakes that could cause widespread damage and casualties in the County and throughout New Jersey. Major earthquakes are infrequent in the State and County and may occur only once every few hundred years or longer, but the consequences of major earthquakes would be very high.

According to the New Jersey Geological and Water Survey (NJGWS), since 2008, Morris County has had nine earthquakes with epicenters in the County and all having a 3.0 magnitude or less. The County has a 1.5% chance of having an earthquake with an epicenter somewhere in Morris County.

In Section 5.3, the identified hazards of concern for Morris County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for earthquake events in the County is considered 'occasional' (hazard event is likely to occur within 100 years see Table 5.3-3).

Climate Change Impacts

Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches the more subject to changing dynamics it becomes. The potential impacts of global climate change on earthquake probability are unknown. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the Earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes (New Jersey State HMP 2014).

Secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity because of the increased saturation. Dams storing increased volumes of water from changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts (New Jersey State HMP 2014).

5.4.3.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the earthquake hazard, the entire County has been identified as the exposed hazard area. Therefore, all assets in Morris County (population, structures, critical facilities and lifelines), as described in the County Profile (Section 4), are vulnerable. The following section includes an evaluation and estimation of the potential impact of the earthquake hazard on Morris County including the following:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2010 Morris County Hazard Mitigation Plan
- Further data collections that will assist understanding this hazard over time

Overview of Vulnerability

Earthquakes usually occur without warning and can impact areas a great distance from their point of origin. The extent of damage depends on the density of population and building and infrastructure construction in the area shaken by the quake. Some areas may be more vulnerable than others based on soil type, the age of the buildings and building codes in place. Compounding the potential for damage – historically, Building Officials Code Administration (BOCA) used in the Northeast were developed to address local concerns including heavy snow loads and wind; seismic requirements for design criteria are not as stringent compared to the west coast's reliance on the more seismically-focused Uniform Building Code). As such, a smaller earthquake in the Northeast can cause more structural damage than if it occurred out west.

Ground shaking is the primary cause of earthquake damage to man-made structures. Damage can be increased when soft soils amplify ground shaking. Soils influence damage in different ways. One way is that soft soils amplify the motion of earthquake waves, producing greater ground shaking and increasing the stresses on structures. Another way is that loose, wet, sandy soils may lose strength and flow as a fluid when shaken, causing foundations and underground structures to shift and break (Stanford 2003).

Damage from earthquakes depends on the location, depth, and magnitude of the earthquake; the thickness and composition of soil and bedrock beneath the area in question; and the types of building structures. Soils influence damage in two ways. Soft soils amplify the motion of earthquake waves, producing greater ground shaking and increasing the stresses on structures. Loose, wet, sandy soils may lose strength and flow as a fluid when shaken (this is known as liquefaction). This causes foundations and underground structures to shift and break.

The entire population and general building stock inventory of the County is at risk of being damaged or experiencing losses due to impacts of an earthquake. Potential losses associated with the earth shaking were calculated for Morris County for three probabilistic earthquake events, the 100-year, 500- and 2,500-year mean return periods (MRP). The impacts on population, existing structures, critical facilities and the economy within Morris County are presented below, following a summary of the data and methodology used.

Data and Methodology

A probabilistic assessment was conducted for Morris County for the 100-, 500- and 2,500-year MRPs through a Level 2 analysis in HAZUS-MH 2.1 to analyze the earthquake hazard and provide a range of loss estimates for Morris County. The probabilistic method uses information from historic earthquakes and inferred faults,

locations and magnitudes, and computes the probable ground shaking levels that may be experienced during a recurrence period by Census tract.

In order to account for the effects of local soil conditions for estimating ground motion and landslide and liquefaction potential, the NEHRP soils as well as liquefaction and landslide susceptibility spatial data created by the New Jersey Geologic and Water Survey were incorporated into HAZUS. As stated earlier, soft soils (NEHRP soil classed D and E) can amplify ground shaking to damaging levels even in a moderate earthquake (NYCEM, 2003). Therefore, buildings located on NEHRP soil classes D and E have an increased risk of damages from an earthquake. In addition, an earthquake can cause liquefaction of certain soil types, a process by which water-saturated sediment temporarily loses strength and acts as a fluid. Further, susceptibility to landsliding during an earthquake is characterized by the geologic group, slope angle and critical acceleration. Refer to Figures 5.4.3-2 through 5.4.3-4 earlier in this section which display NEHRP soils, liquefaction classes and susceptibility of slopes to landsliding during earthquakes in Morris County.

In addition to the probabilistic scenarios mentioned, an annualized loss run was conducted in HAZUS-MH 2.1 to estimate the annualized general building stock dollar losses for the County. The annualized loss methodology combines the estimated losses associated with ground shaking for eight return periods: 100, 250, 500, 750, 1000, 1500, 2000, 2500-year, which are based on values from the USGS seismic probabilistic curves. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction.

As noted in the HAZUS-MH Earthquake User Manual '*Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainly in loss estimates produced by the HAZUS Earthquake Model, possibly at best a factor of two or more.*' However, HAZUS' potential loss estimates are acceptable for the purposes of this HMP.

The occupancy classes available in HAZUS-MH 2.1 were condensed into the following categories (residential, commercial, industrial, agricultural, religious, government, and educational) to facilitate the analysis and the presentation of results. Residential loss estimates address both multi-family and single family dwellings. Impacts to critical facilities and utilities were also evaluated.

Data used to assess this hazard include data available in the HAZUS-MH 2.1 earthquake model, data provided by NJGWS, professional knowledge, and information provided by the County's Planning Committee.

Impact on Life, Health and Safety

Overall, the entire population of Morris County is exposed to an earthquake hazard event. The impact of earthquakes on life, health and safety is dependent upon the severity of the event. Risk to public safety and loss of life from an earthquake in Morris County is minimal with higher risk occurring in buildings as a result of damage to the structure, or people walking below building ornamentation and chimneys that may be shaken loose and fall as a result of the quake.

Populations considered most vulnerable are those located in/near the built environment, particularly near unreinforced masonry construction. In addition, the vulnerable population includes the elderly (persons over the age of 65) and individuals living below the Census poverty threshold. These socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond

during a hazard and the location and construction quality of their housing. Refer to Section 4 (County Profile) for the vulnerable population statistics in Morris County.

An exposure analysis was performed using the NEHRP soils data, the liquefaction susceptibility data, landslide susceptibility data and the 2010 Census data. The sum of the population by Census Block within the NEHRP class "D" and "E" soil types, areas with a liquefaction class of 4, and areas with a landslide susceptibility of class 4 were calculated and summarized in Table 5.4.3-6 below. It is estimated that 174,332 people are exposed to Class "D" and "E" soils, and 30,791 people are exposed to the Class 4 soil liquefaction hazard. None of the population is exposed to the landslide susceptibility hazard.

Table 5.4.3-6. Approximate Population within NEHRP, Liquefaction and Landslide Susceptible Areas

Municipality	Total Population (2010 Census)	Population NEHRP Class "D" and "E" Soils		Population Liquefaction Class 4	
		Number	%	Number	%
Town of Boonton	8,347	0	0%	0	0%
Township of Boonton	4,263	274	6.4%	0	0%
Borough of Butler	7,539	0	0%	0	0%
Chatham Borough	8,962	7,785	86.9%	0	0%
Chatham Township	10,452	6,373	61.0%	0	0%
Chester Borough	1,649	0	0%	0	0%
Chester Township	7,838	112	1.4%	0	0%
Denville Township	16,635	3,100	18.6%	0	0%
Town of Dover	18,157	6,263	34.5%	0	0%
Township of East Hanover	11,157	10,827	97.0%	0	0%
Borough of Florham Park	11,696	11,696	100.0%	0	0%
Township of Hanover	13,712	10,943	79.8%	0	0%
Township of Harding	3,838	403	10.5%	0	0%
Township of Jefferson	21,314	2,481	11.6%	0	0%
Borough of Kinnelon	10,248	175	1.7%	0	0%
Borough of Lincoln Park	10,521	6,788	64.5%	10,521	100%
Township of Long Hill	8,702	2,139	24.6%	0	0%
Borough of Madison	15,845	15,845	100.0%	0	0%
Borough of Mendham	4,981	0	0%	0	0%
Township of Mendham	5,869	0	0%	0	0%
Township of Mine Hill	3,651	371	10.2%	0	0%
Township of Montville	21,528	6,848	31.8%	0	0%
Borough of Morris Plains	5,532	884	16.0%	0	0%
Township of Morris	22,306	8,771	39.3%	0	0%
Town of Morristown	18,411	10,988	59.7%	0	0%

Table 5.4.3-6. Approximate Population within NEHRP, Liquefaction and Landslide Susceptible Areas

Municipality	Total Population (2010 Census)	Population NEHRP Class "D" and "E" Soils		Population Liquefaction Class 4	
		Number	%	Number	%
Borough of Mount Arlington	5,050	279	5.5%	0	0%
Township of Mount Olive	28,117	4,245	15.1%	0	0%
Borough of Mountain Lakes	4,160	0	0%	0	0%
Netcong Borough	3,232	0	0%	0	0%
Township of Parsippany-Troy Hills	53,238	23,930	44.9%	4,730	8.9%
Township of Pequannock	15,540	13,059	84.0%	15,540	100%
Township of Randolph	25,736	875	3.4%	0	0%
Borough of Riverdale	3,559	1,019	28.6%	0	0%
Borough of Rockaway	6,438	1,989	30.9%	0	0%
Township of Rockaway	24,156	480	2.0%	0	0%
Township of Roxbury	23,324	13,363	57.3%	0	0%
Borough of Victory Gardens	1,520	61	4.0%	0	0%
Township of Washington	18,533	1,092	5.9%	0	0%
Borough of Wharton	6,522	874	13.4%	0	0%
Morris County (Total)	**492,276**	**174,332**	**35.4%**	**30,791**	**6.3%**

Sources: NJGWS, 2013, U.S. Census 2010

Residents may be displaced or require temporary to long-term sheltering due to the event. The number of people requiring shelter is generally less than the number displaced as some displaced persons use hotels or stay with family or friends following a disaster event. In HAZUS-MH, estimated sheltering needs for the earthquake hazard are summarized at the Census tract level. Table 5.4.3-7 summarizes the population HAZUS-MH estimates will be displaced or will require short-term sheltering for 500- and 2,500-year MRP by municipality. HAZUS-MH estimates there will be no displaced households or people seeking short-term shelter as a result of the 100-year event.

Table 5.4.3-7. Estimated Displaced Households and Population Seeking Short-Term Shelter from 500- and 2,500-year MRP Events by Municipality

Municipality	500-Year MRP		2,500-Year MRP	
	Displaced Households	People Requiring Short-Term Shelter	Displaced Households	People Requiring Short-Term Shelter
Town of Boonton	0	0	1	0
Township of Boonton	1	0	16	9
Borough of Butler	1	0	11	6
Chatham Borough	1	0	14	6
Chatham Township	2	1	43	21
Chester Borough	0	0	1	1
Chester Township	0	0	1	1

Table 5.4.3-7. Estimated Displaced Households and Population Seeking Short-Term Shelter from 500- and 2,500-year MRP Events by Municipality

Municipality	500-Year MRP		2,500-Year MRP	
	Displaced Households	People Requiring Short-Term Shelter	Displaced Households	People Requiring Short-Term Shelter
Denville Township	0	0	10	5
Town of Dover	2	2	44	39
Township of East Hanover	1	0	14	8
Borough of Florham Park	1	0	13	7
Township of Hanover	1	0	16	8
Township of Harding	0	0	1	0
Township of Jefferson	0	0	4	2
Borough of Kinnelon	0	0	1	1
Borough of Lincoln Park	2	1	73	38
Township of Long Hill	0	0	11	6
Borough of Madison	2	1	47	28
Borough of Mendham	0	0	2	1
Township of Mendham	0	0	1	1
Township of Mine Hill	0	0	1	1
Township of Montville	0	0	7	4
Borough of Morris Plains	0	0	3	2
Township of Morris	1	1	25	13
Town of Morristown	4	3	87	55
Borough of Mount Arlington	0	0	5	2
Township of Mount Olive	2	1	44	23
Borough of Mountain Lakes	0	0	1	0
Netcong Borough	0	0	3	2
Township of Parsippany-Troy Hills	5	3	125	66
Township of Pequannock	2	1	85	46
Township of Randolph	1	1	22	11
Borough of Riverdale	0	0	1	0
Borough of Rockaway	1	0	18	10
Township of Rockaway	0	0	10	5
Township of Roxbury	1	1	28	16
Borough of Victory Gardens	0	0	3	2
Township of Washington	0	0	4	3
Borough of Wharton	0	0	8	5
Morris County (Total)	**34**	**20**	**803**	**453**

Source: HAZUS-MH 2.1
Note: The number of displaced households and persons seeking shelter was calculated using the 2000 U.S. Census data (HAZUS-MH 2.1 default demographic data).

According to the 1999-2003 NYCEM Summary Report (*Earthquake Risks and Mitigation in the New York / New Jersey / Connecticut Region*), there is a strong correlation between structural building damage and the number of injuries and casualties from an earthquake event. Further, the time of day also exposes different sectors of the community to the hazard. For example, HAZUS considers the residential occupancy at its maximum at 2:00 a.m., where the educational, commercial and industrial sectors are at their maximum at 2:00 p.m., and peak commute time is at 5:00 p.m. Whether directly impacted or indirectly impact, the entire population will have to deal with the consequences of earthquakes to some degree. Business interruption could keep people from working, road closures could isolate populations, and loss of functions of utilities could impact populations that suffered no direct damage from an event itself.

There are no injuries or casualties estimated for the 100-year event. Table 5.4.3-8 and Table 5.4.3-9 summarize the County-wide injuries and casualties estimated for the 500- and 2,500-year MRP earthquake events, respectively.

Table 5.4.3-8. Estimated Number of Injuries and Casualties from the 500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	15	22	18
Hospitalization	2	2	2
Casualties	0	0	0

Source: HAZUS-MH 2.1

Table 5.4.3-9. Estimated Number of Injuries and Casualties from the 2,500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	224	258	288
Hospitalization	37	70	64
Casualties	6	13	11

Source: HAZUS-MH 2.1

Impact on General Building Stock

After considering the population vulnerable to the earthquake hazard, the value of general building stock exposed to and damaged by 100-, 500- and 2,500-year MRP earthquake events was evaluated. In addition, annualized losses were calculated using HAZUS-MH 2.1. The entire County's general building stock is considered at risk and exposed to this hazard.

As stated earlier, soft soils (NEHRP soil classed D and E) can amplify ground shaking to damaging levels even in a moderate earthquake (NYCEM, 2003). Therefore, buildings located on NEHRP soil classes D and E have an increased risk of damages from an earthquake. In addition, areas with an identified class 4 susceptibility of liquefaction and landslide may have the potential to further increase the effects of an earthquake. There are no buildings located in areas of landslide susceptibility class 4. Tables 5.4.3-10 and 5.4.3-11 summarize the number and value of buildings in Morris County located within these defined areas.

Table 5.4.3-10. Number of Buildings within NEHRP, Liquefaction and Landslide Susceptible Areas

Municipality	Number of Buildings	Buildings NEHRP Class "D" and "E" Soils		Buildings Liquefaction Class 4	
		Number	%	Number	%
Town of Boonton	3,210	31	1.0%	0	0%
Township of Boonton	1,853	112	6.0%	0	0%
Borough of Butler	2,725	0	0%	0	0%
Chatham Borough	3,245	2,790	86.0%	0	0%
Chatham Township	3,998	2,401	60.1%	0	0%
Chester Borough	859	0	0%	0	0%
Chester Township	3,587	68	1.9%	0	0%
Denville Township	7,032	1,347	19.2%	0	0%
Town of Dover	4,385	1,327	30.3%	0	0%
Township of East Hanover	4,776	4,708	98.6%	0	0%
Borough of Florham Park	3,722	3,722	100.0%	0	0%
Township of Hanover	7,045	5,626	79.9%	0	0%
Township of Harding	2,050	189	9.2%	0	0%
Township of Jefferson	9,281	1,050	11.3%	0	0%
Borough of Kinnelon	4,078	76	1.9%	0	0%
Borough of Lincoln Park	4,184	2,099	50.2%	4,184	100%
Township of Long Hill	3,515	452	12.9%	0	0%
Borough of Madison	6,235	6,235	100.0%	0	0%
Borough of Mendham	2,054	0	0%	0	0%
Township of Mendham	2,545	0	0%	0	0%
Township of Mine Hill	1,555	198	12.7%	0	0%
Township of Montville	8,066	2,203	27.3%	9	0.1%
Borough of Morris Plains	2,361	297	12.6%	0	0%
Township of Morris	9,488	4,135	43.6%	0	0%
Town of Morristown	4,935	2,591	52.5%	0	0%
Borough of Mount Arlington	2,303	64	2.8%	0	0%
Township of Mount Olive	8,525	1,378	16.2%	0	0%
Borough of Mountain Lakes	1,589	0	0%	0	0%
Netcong Borough	1,075	2	0.2%	0	0%
Township of Parsippany-Troy Hills	17,033	6,932	40.7%	1,359	8.0%
Township of Pequannock	5,586	5,289	94.7%	5,586	100%
Township of Randolph	8,375	286	3.4%	0	0%
Borough of Riverdale	1,155	558	48.3%	3	0.3%
Borough of Rockaway	2,580	830	32.2%	0	0%
Township of Rockaway	11,215	449	4.0%	0	0%

Table 5.4.3-10. Number of Buildings within NEHRP, Liquefaction and Landslide Susceptible Areas

Municipality	Number of Buildings	Buildings NEHRP Class "D" and "E" Soils		Buildings Liquefaction Class 4	
		Number	%	Number	%
Township of Roxbury	9,408	5,567	59.2%	0	0%
Borough of Victory Gardens	338	41	12.1%	0	0%
Township of Washington	7,793	484	6.2%	0	0%
Borough of Wharton	2,040	241	11.8%	0	0%
Morris County (Total)	**185,799**	**63,778**	**34.3%**	**11,141**	**6.0%**

Sources: NJGWS, 2013, Morris County

Table 5.4.3-11. Replacement Value of Buildings within NEHRP, Liquefaction and Landslide Susceptible Areas

Municipality	Total Replacement Value (Structure and Contents)	Replacement Value in NEHRP Class "D" and "E" Soils		Replacement Value in Liquefaction Class 4	
		Amount	%	Amount	%
Town of Boonton	$2,359,806,704	$38,752,115	1.6%	0	0%
Township of Boonton	$1,657,854,494	$157,655,938	9.5%	0	0%
Borough of Butler	$1,818,159,072	$0	0%	0	0%
Chatham Borough	$2,112,769,732	$1,785,862,623	84.5%	0	0%
Chatham Township	$3,234,872,840	$1,837,153,057	56.8%	0	0%
Chester Borough	$798,032,736	$0	0%	0	0%
Chester Township	$3,763,335,644	$32,506,595	0.9%	0	0%
Denville Township	$5,687,212,965	$1,025,934,976	18.0%	0	0%
Town of Dover	$3,075,745,326	$1,107,239,120	36.0%	0	0%
Township of East Hanover	$5,401,896,233	$5,343,402,997	98.9%	0	0%
Borough of Florham Park	$3,991,843,257	$3,991,843,257	100.0%	0	0%
Township of Hanover	$6,582,774,313	$5,832,239,961	88.6%	0	0%
Township of Harding	$2,344,644,664	$159,070,299	6.8%	0	0%
Township of Jefferson	$5,074,333,318	$564,724,822	11.1%	0	0%
Borough of Kinnelon	$3,942,612,191	$70,196,145	1.8%	0	0%
Borough of Lincoln Park	$2,521,331,492	$1,398,853,536	55.5%	$2,521,331,492	100%
Township of Long Hill	$2,686,329,094	$366,757,382	13.7%	0	0%
Borough of Madison	$4,038,218,735	$4,038,218,735	100.0%	0	0%
Borough of Mendham	$1,938,234,052	$0	0%	0	0%
Township of Mendham	$2,900,551,737	$0	0%	0	0%
Township of Mine Hill	$968,302,365	$68,413,253	7.1%	0	0%
Township of Montville	$7,935,508,932	$2,505,418,275	31.6%	$8,129,151	0.1%
Borough of Morris Plains	$2,353,504,441	$258,618,173	11.0%	0	0%
Township of Morris	$8,423,230,635	$3,706,066,953	44.0%	0	0%
Town of Morristown	$4,131,251,475	$2,614,011,945	63.3%	0	0%

Table 5.4.3-11. Replacement Value of Buildings within NEHRP, Liquefaction and Landslide Susceptible Areas

Municipality	Total Replacement Value (Structure and Contents)	Replacement Value in NEHRP Class "D" and "E" Soils		Replacement Value in Liquefaction Class 4	
		Amount	%	Amount	%
Borough of Mount Arlington	$1,698,506,114	$74,470,877	4.4%	0	0%
Township of Mount Olive	$7,726,519,709	$855,087,336	11.1%	0	0%
Borough of Mountain Lakes	$1,470,833,586	$0	0%	0	0%
Netcong Borough	$936,477,404	$3,476,676	0.4%	0	0%
Township of Parsippany-Troy Hills	$14,262,637,338	$6,586,088,913	46.2%	$1,180,858,668	8.3%
Township of Pequannock	$4,903,988,440	$4,158,582,911	84.8%	$4,903,988,440	100%
Township of Randolph	$8,283,021,151	$392,070,107	4.7%	0	0%
Borough of Riverdale	$1,246,580,332	$499,525,267	40.1%	$1,116,693	0.1%
Borough of Rockaway	$1,804,154,071	$635,538,036	35.2%	0	0%
Township of Rockaway	$7,782,228,135	$719,685,218	9.2%	0	0%
Township of Roxbury	$6,601,093,651	$4,021,480,238	60.9%	0	0%
Borough of Victory Gardens	$138,840,857	$34,585,111	24.9%	0	0%
Township of Washington	$6,580,308,267	$373,040,169	5.7%	0	0%
Borough of Wharton	$1,699,397,922	$615,592,630	36.2%	0	0%
Morris County (Total)	**$154,876,943,422**	**$55,872,163,644**	**36.1%**	**$8,615,424,443**	**5.6%**

Sources: NJGWS, 2013, Morris County

The HAZUS-MH 2.1 model estimates the value of the exposed building stock and the loss (in terms of damage to the exposed stock). Refer to Table 4-7 in the County Profile (Section 4) for general building stock statistics (structure and contents).

For this plan update, a HAZUS-MH probabilistic model was run to estimate annualized dollar losses for Morris County. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction. Please note that annualized loss does not predict what losses will occur in any particular year. The estimated annualized losses are approximately $2.3 million per year (building and contents) for the County.

According to NYCEM, where earthquake risks and mitigation were evaluated in the New York, New Jersey and Connecticut region, most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking (NYCEM, 2003). NYCEM indicates there is a strong correlation between PGA and the damage a building might experience. The HAZUS-MH model is based on the best available earthquake science and aligns with these statements. HAZUS-MH 2.1 methodology and model were used to analyze the earthquake hazard for the general building stock for Morris County. See Figure 5.4.3-5 through Figure 5.4.3-7 earlier in this profile that illustrates the geographic distribution of PGA (g) across the County for 100-, 500- and 2,500-year MRP events at the Census-tract level.

In addition, according to NYCEM, a building's construction determines how well it can withstand the force of an earthquake. The NYCEM report indicates that un-reinforced masonry buildings are most at risk during an earthquake because the walls are prone to collapse outward, whereas steel and wood buildings absorb more of the earthquake's energy. Additional attributes that contribute to a building's capability to withstand an

earthquake's force include its age, number of stories and quality of construction. HAZUS-MH considers building construction and the age of buildings as part of the analysis.

Potential building damage was evaluated by HAZUS-MH 2.1 across the following damage categories (none, slight, moderate, extensive and complete). Table 5.4.3-12 provides definitions of these five categories of damage for a light wood-framed building; definitions for other building types are included in HAZUS-MH technical manual documentation. General building stock damage for these damage categories by occupancy class and building type on a County-wide basis is summarized below for the 100-, 500- and 2,500-year events.

Table 5.4.3-12. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
Slight	Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations.
Complete	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Tables 5.4.3-13 through 5.4.3-15 summarize the damage estimated for the 100-, 500- and 2,500-year MRP earthquake events. Damage loss estimates include structural and non-structural damage to the building and loss of contents.

Table 5.4.3-13. Estimated Buildings Damaged by General Occupancy for 100-year and 500-year MRP Earthquake Events

	Average Damage State									
	100-Year MRP					500-Year MRP				
Category	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Residential	167,465 (90.1%)	14 (<1%)	2 (<1%)	0 (0%)	0 (0%)	163,383 (87.9%)	3,434 (1.8%)	605 (<1%)	54 (<1%)	5 (<1%)
Commercial	8,428 (4.5%)	1 (<1%)	0 (0%)	0 (0%)	0 (0%)	8,119 (4.4%)	231 (<1%)	72 (<1%)	8 (<1%)	1 (<1%)
Industrial	1,850 (<1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1,776 (<1%)	53 (<1%)	19 (<1%)	2 (<1%)	0 (0%)
Education, Government, Religious and Agricultural	8,037 (4.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	7,798 (4.2%)	180 (<1%)	53 (<1%)	6 (<1%)	0 (0%)

Source: HAZUS-MH 2.1

Table 5.4.3-14. Estimated Buildings Damaged by General Occupancy for 2, 500-year MRP Earthquake Events

	Average Damage State				
	2,500-Year MRP				
Category	None	Slight	Moderate	Extensive	Complete
Residential	132,626 (73.5%)	25,460 (13.7%)	7,941 (4.3%)	1,272 (<1%)	181 (<1%)
Commercial	5,969 (3.2%)	1,355 (<1%)	878 (<1%)	199 (<1%)	28 (<1%)

Category	Average Damage State 2,500-Year MRP None	Slight	Moderate	Extensive	Complete
Industrial	1,298 (<1%)	283 (<1%)	210 (<1%)	54 (<1%)	6 (<1%)
Education, Government, Religious and Agricultural	7,393 (4.0%)	1,132 (<1%)	651 (<1%)	141 (<1%)	19 (<1%)

Source: HAZUS-MH 2.1

Table 5.4.3-15. Estimated Value (Building and Contents) Damaged by the 500- and 2,500-Year MRP Earthquake Events

Municipality	Total Improved Value (Building and Contents)	Estimated Total Damages* Annualized Loss	100-Year	500-Year	2,500-Year	Percent of Total Building and Contents * Annualized Loss	100-Year	500-Year	2,500-Year
Town of Boonton	$2,359,806,704	$17,295	$0	$925,880	$19,353,424	<1%	0%	<1%	<1%
Township of Boonton	$1,657,854,494	$26,268	$0	$1,333,249	$29,271,016	<1%	0%	<1%	1.8%
Borough of Butler	$1,818,159,072	$19,748	$0	$1,026,313	$22,053,099	<1%	0%	<1%	1.2%
Chatham Borough	$2,112,769,732	$33,927	$0	$1,912,686	$35,680,217	<1%	0%	<1%	1.7%
Chatham Township	$3,234,872,840	$130,516	$97,089	$8,877,506	$119,431,828	<1%	<1%	<1%	3.7%
Chester Borough	$798,032,736	$7,677	$0	$402,915	$8,045,882	<1%	0%	<1%	1.0%
Chester Township	$3,763,335,644	$33,736	$0	$1,834,508	$37,120,794	<1%	0%	<1%	<1%
Denville Township	$5,687,212,965	$60,980	$0	$3,181,873	$67,488,917	<1%	0%	<1%	1.2%
Town of Dover	$3,075,745,326	$55,916	$0	$3,366,802	$54,535,966	<1%	0%	<1%	1.8%
Township of East Hanover	$5,401,896,233	$130,040	$0	$7,557,324	$127,506,295	<1%	0%	<1%	2.4%
Borough of Florham Park	$3,991,843,257	$92,471	$0	$5,446,065	$90,347,996	<1%	0%	<1%	2.3%
Township of Hanover	$6,582,774,313	$131,980	$0	$7,461,258	$131,472,185	<1%	0%	<1%	2.0%
Township of Harding	$2,344,644,664	$24,033	$0	$1,242,555	$27,319,676	<1%	0%	<1%	1.2%
Township of Jefferson	$5,074,333,318	$30,498	$0	$1,627,664	$34,444,886	<1%	0%	<1%	<1%
Borough of Kinnelon	$3,942,612,191	$29,468	$0	$1,523,740	$34,225,682	<1%	0%	<1%	<1%
Borough of Lincoln Park	$2,521,331,492	$84,758	$59,357	$4,922,453	$81,410,359	<1%	<1%	<1%	3.2%
Township of Long Hill	$2,686,329,094	$46,736	$0	$2,720,725	$48,305,295	<1%	0%	<1%	1.8%
Borough of Madison	$4,038,218,735	$87,307	$0	$5,230,219	$87,773,357	<1%	0%	<1%	2.2%
Borough of Mendham	$1,938,234,052	$18,516	$0	$981,822	$20,520,671	<1%	0%	<1%	1.1%
Township of Mendham	$2,900,551,737	$26,729	$0	$1,428,256	$30,099,847	<1%	0%	<1%	1.0%
Township of Mine Hill	$968,302,365	$9,473	$0	$513,682	$10,390,839	<1%	0%	<1%	1.1%
Township of Montville	$7,935,508,932	$38,100	$0	$1,774,457	$45,997,990	<1%	0%	<1%	<1%
Borough of Morris Plains	$2,353,504,441	$25,952	$0	$1,308,234	$28,310,113	<1%	0%	<1%	1.2%
Township of Morris	$8,423,230,635	$124,679	$0	$6,972,582	$130,965,086	<1%	0%	<1%	1.6%

Table 5.4.3-15. Estimated Value (Building and Contents) Damaged by the 500- and 2,500-Year MRP Earthquake Events

Municipality	Total Improved Value (Building and Contents)	Estimated Total Damages*				Percent of Total Building and Contents *			
		Annualized Loss	100-Year	500-Year	2,500-Year	Annualized Loss	100-Year	500-Year	2,500-Year
Town of Morristown	$4,131,251,475	$84,635	$0	$4,863,396	$82,866,386	<1%	0%	<1%	2.0%
Borough of Mount Arlington	$1,698,506,114	$16,165	$0	$876,331	$17,658,545	<1%	0%	<1%	1.0%
Township of Mount Olive	$7,726,519,709	$79,364	$0	$4,484,839	$82,637,921	<1%	0%	<1%	1.1%
Borough of Mountain Lakes	$1,470,833,586	$15,512	$0	$829,216	$17,358,911	<1%	0%	<1%	1.2%
Netcong Borough	$936,477,404	$8,726	$0	$467,238	$9,295,996	<1%	0%	<1%	<1%
Township of Parsippany-Troy Hills	$14,262,637,338	$247,980	$0	$13,740,758	$251,100,452	<1%	0%	<1%	1.8%
Township of Pequannock	$4,903,988,440	$209,074	$120,418	$12,119,830	$199,075,596	<1%	<1%	<1%	4.1%
Township of Randolph	$8,283,021,151	$83,362	$0	$4,506,912	$91,563,394	<1%	0%	<1%	1.1%
Borough of Riverdale	$1,246,580,332	$4,529	$0	$200,700	$5,643,878	<1%	0%	<1%	<1%
Borough of Rockaway	$1,804,154,071	$38,358	$0	$2,318,992	$37,293,813	<1%	0%	<1%	2.1%
Township of Rockaway	$7,782,228,135	$50,278	$0	$2,535,942	$56,837,826	<1%	0%	<1%	<1%
Township of Roxbury	$6,601,093,651	$99,254	$0	$5,889,904	$99,463,163	<1%	0%	<1%	1.5%
Borough of Victory Gardens	$138,840,857	$1,346	$0	$71,094	$1,434,230	<1%	0%	<1%	1.0%
Township of Washington	$6,580,308,267	$54,347	$0	$2,954,599	$59,094,141	<1%	0%	<1%	<1%
Borough of Wharton	$1,699,397,922	$17,777	$0	$930,063	$19,032,994	<1%	0%	<1%	1.1%
Morris County (Total)	**$154,876,943,422**	**$2,297,507**	**$276,864**	**$130,362,580**	**$2,352,428,663**	**<1%**	**<1%**	**<1%**	**1.5%**

Source: HAZUS-MH 2.1

**Total Damages is the sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government).*

Table 5.4.3-16. Estimated Value (Building and Contents) Damaged by the 100-, 500- and 2,500-Year MRP Earthquake Events (Continued)

Municipality	Total Improved Value (Building and Contents)	Estimated Residential Damage			Estimated Commercial Damage		
		100-Year	500-Year	2,500-Year	100-Year	500-Year	2,500-Year
Town of Boonton	$2,359,806,704	$0	$738,811	$15,420,147	$0	$21,334	$420,467
Township of Boonton	$1,657,854,494	$0	$874,952	$19,447,700	$0	$175,038	$3,601,058
Borough of Butler	$1,818,159,072	$0	$729,776	$15,905,289	$0	$141,215	$2,857,431
Chatham Borough	$2,112,769,732	$0	$1,357,188	$26,139,221	$0	$325,125	$5,503,049
Chatham Township	$3,234,872,840	$88,732	$7,941,107	$107,076,783	$3,990	$322,951	$3,996,215
Chester Borough	$798,032,736	$0	$169,439	$3,425,525	$0	$159,996	$3,129,232
Chester Township	$3,763,335,644	$0	$1,518,244	$30,703,543	$0	$80,350	$1,580,032

Table 5.4.3-16. Estimated Value (Building and Contents) Damaged by the 100-, 500- and 2,500-Year MRP Earthquake Events (Continued)

Municipality	Total Improved Value (Building and Contents)	Estimated Residential Damage			Estimated Commercial Damage		
		100-Year	500-Year	2,500-Year	100-Year	500-Year	2,500-Year
Denville Township	$5,687,212,965	$0	$2,320,287	$49,708,599	$0	$356,406	$7,209,203
Town of Dover	$3,075,745,326	$0	$1,763,681	$29,567,966	$0	$553,006	$8,496,861
Township of East Hanover	$5,401,896,233	$0	$3,981,435	$70,184,652	$0	$2,001,320	$32,054,192
Borough of Florham Park	$3,991,843,257	$0	$2,868,874	$49,635,269	$0	$1,358,615	$21,491,087
Township of Hanover	$6,582,774,313	$0	$3,670,163	$67,517,516	$0	$2,086,868	$34,891,454
Township of Harding	$2,344,644,664	$0	$1,029,092	$22,689,023	$0	$57,626	$1,201,763
Township of Jefferson	$5,074,333,318	$0	$1,334,264	$28,330,221	$0	$180,735	$3,637,078
Borough of Kinnelon	$3,942,612,191	$0	$1,329,261	$30,197,785	$0	$69,856	$1,442,935
Borough of Lincoln Park	$2,521,331,492	$45,130	$3,618,762	$61,557,228	$1,617	$183,106	$3,195,302
Township of Long Hill	$2,686,329,094	$0	$1,897,347	$34,756,004	$0	$396,873	$6,429,827
Borough of Madison	$4,038,218,735	$0	$3,710,336	$63,744,850	$0	$687,305	$10,889,766
Borough of Mendham	$1,938,234,052	$0	$752,234	$15,849,487	$0	$80,268	$1,602,028
Township of Mendham	$2,900,551,737	$0	$1,253,243	$26,405,723	$0	$6,626	$131,770
Township of Mine Hill	$968,302,365	$0	$404,872	$8,191,503	$0	$35,069	$676,685
Township of Montville	$7,935,508,932	$0	$1,382,082	$34,670,671	$0	$104,385	$2,648,343
Borough of Morris Plains	$2,353,504,441	$0	$729,660	$15,852,059	$0	$243,136	$5,010,574
Township of Morris	$8,423,230,635	$0	$4,813,383	$93,877,074	$0	$1,001,389	$16,617,990
Town of Morristown	$4,131,251,475	$0	$2,315,091	$40,901,311	$0	$1,932,540	$31,608,210
Borough of Mount Arlington	$1,698,506,114	$0	$770,555	$15,586,038	$0	$59,301	$1,160,469
Township of Mount Olive	$7,726,519,709	$0	$2,822,380	$50,869,644	$0	$451,420	$8,235,742
Borough of Mountain Lakes	$1,470,833,586	$0	$619,028	$13,140,440	$0	$97,835	$1,961,323
Netcong Borough	$936,477,404	$0	$312,556	$6,198,889	$0	$62,300	$1,187,858
Township of Parsippany-Troy Hills	$14,262,637,338	$0	$7,141,196	$136,426,089	$0	$4,037,094	$69,798,500
Township of Pequannock	$4,903,988,440	$75,679	$7,955,613	$136,509,052	$25,757	$1,708,934	$23,809,887
Township of Randolph	$8,283,021,151	$0	$3,278,171	$67,478,416	$0	$404,250	$7,699,689
Borough of Riverdale	$1,246,580,332	$0	$112,162	$3,030,567	$0	$60,002	$1,656,983
Borough of Rockaway	$1,804,154,071	$0	$1,305,293	$21,386,097	$0	$542,247	$8,488,621
Township of Rockaway	$7,782,228,135	$0	$1,645,436	$36,081,072	$0	$445,457	$8,841,429
Township of Roxbury	$6,601,093,651	$0	$3,748,203	$64,063,033	$0	$1,204,784	$20,181,736
Borough of Victory Gardens	$138,840,857	$0	$43,287	$883,808	$0	$19,553	$377,550
Township of Washington	$6,580,308,267	$0	$2,307,404	$45,870,729	$0	$111,285	$2,167,557
Borough of Wharton	$1,699,397,922	$0	$507,529	$10,267,130	$0	$107,696	$2,077,821
Morris County (Total)	**$154,876,943,422**	**$209,541**	**$85,072,396**	**$1,569,546,152**	**$31,364**	**$21,873,294**	**$367,967,718**

Source: HAZUS-MH 2.1

HAZUS-MH estimates approximately $277 thousand in damages for the 100-year earthquake event. It is also estimated that there may be $130 million (<1%) in damages to buildings in the County during a 500-year earthquake event. These includes structural damage, non-structural damage and loss of contents, representing less than 1% of the total improved value for general building stock in Morris County. For a 2,500-year MRP

earthquake event, HAZUS-MH estimates greater than $2.3 billion, approximately 1.5% of the total general building stock improved value. Residential and commercial buildings account for most of the damage for earthquake events.

Earthquakes can cause secondary hazard events such as fires. Zero fires are anticipated as a result of the 100-, 500- and 2,500-year MRP events.

Impact on Critical Facilities

After considering the general building stock exposed to, and damaged by, 100-, 500- and 2,500-year MRP earthquake events, critical facilities were evaluated. All critical facilities (essential facilities, transportation systems, lifeline utility systems, high-potential loss facilities and user-defined facilities) in Morris County are considered exposed and potentially vulnerable to the earthquake hazard. Refer to subsection "Critical Facilities" in Section 4 (County Profile) of this Plan for a description of the critical facilities in the County.

To estimate critical facilities exposure to the potential impacts of an earthquake an exposure analysis was performed using the NEHRP soils data, liquefaction and landslide susceptibility data to determine the critical facility's location in relation to these areas. The critical facilities and utilities in the areas were calculated and summarized in the tables below.

Table 5.4.3-17. Number of Critical Facilities Located in the NEHRP Soil Class D and E

Municipality	Facility Types																							
	Air	Bus	Communication	Dam	DPW	Electric Power	Electric Substation	EMS	Emergency Operation Center	Fire Station	Hazardous Material	Library	Medical Facility	Municipal Hall	Natural Gas	Nuclear Power Plant	Oil Facility	Police Station	Potable Water Facility	Potable Pump	Rail Facility	School	Senior	Shelter	Wastewater Facility
Town of Boonton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Boonton	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Butler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chatham Borough	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	6	0	0	1
Chatham Township	0	0	0	0	1	0	0	1	0	2	1	0	0	0	0	0	0	1	0	0	0	4	1	0	1
Chester Borough	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chester Township	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denville Township	0	1	0	2	0	0	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	3	0	0	0
Town of Dover	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	1	1	0	0
Township of East Hanover	0	0	0	0	1	0	1	1	1	2	4	1	0	1	0	0	0	1	0	0	0	6	0	2	0
Borough of Florham Park	0	0	0	0	1	0	0	1	1	2	2	2	0	1	0	0	0	1	0	0	0	7	2	0	1
Township of Hanover	1	0	2	2	3	0	0	0	1	2	1	2	0	1	3	1	3	1	0	0	0	10	1	0	2
Township of Harding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Jefferson	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Kinnelon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Lincoln Park	1	0	0	0	1	0	0	0	0	2	0	1	0	0	0	0	0	1	0	0	1	4	0	0	2

Table 5.4.3-17. Number of Critical Facilities Located in the NEHRP Soil Class D and E

Municipality	Facility Types																								
	Air	Bus	Communication	Dam	DPW	Electric Power	Electric Substation	EMS	Emergency Operation Center	Fire Station	Hazardous Material	Library	Medical Facility	Municipal Hall	Natural Gas	Nuclear Power Plant	Oil Facility	Police Station	Potable Water Facility	Potable Pump	Rail Facility	School	Senior	Shelter	Wastewater Facility
Township of Long Hill	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2
Borough of Madison	0	0	1	0	1	0	0	1	1	1	0	1	0	1	0	0	0	1	1	0	1	10	1	3	0
Borough of Mendham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Mendham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Mine Hill	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Montville	0	2	0	1	1	0	0	1	1	2	1	0	0	1	0	0	0	0	0	1	0	2	0	1	0
Borough of Morris Plains	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
Township of Morris	0	0	0	0	0	0	0	0	1	2	2	0	0	1	0	0	0	1	0	0	1	6	0	1	2
Town of Morristown	0	1	0	2	0	2	0	0	1	1	0	1	1	1	0	0	0	1	0	0	1	6	2	0	0
Borough of Mount Arlington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Township of Mount Olive	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Mountain Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netcong Borough	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Parsippany-Troy Hills	0	1	1	5	1	1	0	2	0	5	3	1	0	0	1	0	0	1	1	0	0	10	2	1	1
Township of Pequannock	0	0	0	0	1	0	0	1	1	2	0	1	1	1	0	0	0	1	0	0	0	9	0	0	0
Township of Randolph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Riverdale	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0
Borough of Rockaway	0	0	0	0	1	0	0	1	1	1	2	1	0	1	0	0	0	1	1	0	0	4	0	0	0
Township of Rockaway	0	0	0	0	2	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Township of Roxbury	0	0	0	0	1	0	0	1	1	3	1	1	0	1	1	0	0	0	0	0	2	8	0	0	1
Borough of Victory Gardens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Washington	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Borough of Wharton	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morris County (Total)	**2**	**6**	**6**	**17**	**17**	**3**	**2**	**11**	**16**	**36**	**20**	**16**	**2**	**16**	**5**	**1**	**3**	**16**	**4**	**1**	**9**	**97**	**10**	**8**	**14**

Source: NJGWS, 2013, Morris County, HAZUS-MH
Note: DPW – Department of Public Works
EMS – Emergency Medical Services

Table 5.4.3-18. Number of Critical Facilities Located in the Liquefaction Susceptibility Class 4

Municipality	Facility Types														
	Air	Bus	Communication	DPW	EMS	Emergency Operation Center	Fire Station	Library	Medical	Municipal Hall	Police Station	Rail Facility	School	Senior	Wastewater Facility
Town of Boonton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Boonton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Butler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chatham Borough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chatham Township	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chester Borough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chester Township	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denville Township	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Town of Dover	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of East Hanover	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Florham Park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Hanover	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Harding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Kinnelon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Lincoln Park	1	0	0	1	1	1	2	1	0	1	1	1	4	2	2
Township of Long Hill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Madison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Mendham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Mendham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Mine Hill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Montville	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Morris Plains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Morris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Town of Morristown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Mount Arlington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Mount Olive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Mountain Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Netcong Borough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Parsippany-Troy Hills	0	1	1	0	1	0	1	0	0	0	0	0	2	0	1
Township of Pequannock	0	0	0	1	1	1	2	1	1	1	1	0	9	1	0
Township of Randolph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Riverdale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.4.3-18. Number of Critical Facilities Located in the Liquefaction Susceptibility Class 4

Municipality	Facility Types														
	Air	Bus	Communication	DPW	EMS	Emergency Operation Center	Fire Station	Library	Medical	Municipal Hall	Police Station	Rail Facility	School	Senior	Wastewater Facility
Borough of Rockaway	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Rockaway	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Roxbury	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Victory Gardens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Township of Washington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Borough of Wharton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morris County (Total)	**1**	**1**	**1**	**2**	**3**	**2**	**5**	**2**	**1**	**2**	**2**	**1**	**15**	**3**	**3**

Source: NJGWS, 2013, Morris County, HAZUS-MH
Note: EMS – Emergency Medical Services
DPW – Department of Public Works

HAZUS-MH 2.1 estimates the probability that critical facilities may sustain damage as a result of 100-, 500- and 2,500-year MRP earthquake events. Additionally, HAZUS-MH estimates percent functionality for each facility days after the event. As a result of a 100-Year MRP event, HAZUS-MH 2.1 estimates that emergency facilities (police, fire, EMS and medical facilities), schools, utilities and specific facilities identified by Morris County as critical will be nearly 100% functional. Therefore, the impact to critical facilities is not significant for the 100-year event.

Table 5.4.3-19 and Table 5.4.3-20 lists the percent probability of critical facilities sustaining the damage category as defined by the column heading and percent functionality after the event for the 500-year and 2,500-year MRP earthquake events.

Table 5.4.3-19. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities in Morris County for the 500-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	84-96	3-11	1-5	0.1-1	<1	84-96	94-99	99-100	99-100
Police	84-98	1-11	0.3-5	<1	<1	84-98	94-100	99-100	99-100
Fire	84-98	1-11	0.3-5	<1	<1	84-98	94-100	99-100	99-100
EOC	74-96	3-9	0.8-5	<1	<1	74-96	88-99	97-100	99-100
School	84-98	1-11	0.3-5	<1	<1	84-98	94-100	99-100	99-100
Utilities									
Potable Water	92-98	0.2-8	<1	0	0	97-100	100	100	100
Wastewater	74-98	2-23	0.1-4	<1	0	81-99	100	100	100
Electric	92-99	1-8	<1	0	0	96-99	100	100	100

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communication	92-100	0.4-8	<1	0	0	100	100	100	100

Source: HAZUS-MH 2.1

Table 5.4.3-20. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities in Morris County for the 2,500-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	24-74	16-22	8-23	2-10	0.2-23	24-74	44-89	67-98	72-99
Police	24-86	10-23	4-23	0.7-10	0.1-23	24-86	44-95	67-99	72-100
Fire	24-86	10-23	4-25	0.7-11	0.1-23	24-86	44-95	67-99	72-100
EOC	18-75	15-23	8-20	2-8	0.2-11	18-75	35-90	59-98	66-99
School	24-86	10-22	4-23	0.7-11	0.1-23	24-86	44-95	67-99	72-100
Utilities									
Potable Water	22-96	3-44	1-29	0-6	0-5	57-98	92-100	97-100	100
Wastewater	10-45	34-44	14-39	1-13	0.1-5	26-59	79-97	84-99	94-100
Electric	22-80	12-43	8-29	0.4-6	0.1-6	46-87	94-100	97-100	100
Communication	22-79	12-44	6-29	0.4-6	0-2	78-81	96-97	99-100	100

Source: HAZUS-MH 2.1

Impact on Economy

The risk of a damaging earthquake, in combination with the density of value of buildings in New Jersey, place the State 10th among all states for potential economic loss from earthquakes (Stanford 2003).

Earthquakes also have impacts on the economy, including: loss of business function, damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. A Level 2 HAZUS-MH analysis estimates the total economic loss associated with each earthquake scenario, which includes building- and lifeline-related losses (transportation and utility losses) based on the available inventory (facility [or GIS point] data only). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" subsection discussed earlier in this section. Lifeline-related losses include the direct repair cost to transportation and utility systems and are reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion. Additionally, economic loss includes business interruption losses associated with the inability to operate a business due to the damage sustained during the earthquake as well as temporary living expenses for those displaced. These losses are discussed below.

HAZUS-MH 2.1 estimates the County will incur approximately $40 thousand in income losses (wage, rental, relocation and capital-related losses) in addition to approximately $320 thousand in structural, non-structural, content and inventory losses.

It is significant to note that for the 500-year event, HAZUS-MH 2.1 estimates the County will incur approximately $14.1 million in income losses (wage, rental, relocation and capital-related losses) in addition to the 500-year event structural, non-structural, content and inventory losses ($130.9 million).

For the 2,500-year event, HAZUS-MH 2.1 estimates the County will incur approximately $215.8 million in income losses, mainly to the commercial and residential occupancy classes associated with wage, rental, relocation and capital-related losses. In addition, the 2,500-year event structural, non-structural, content and inventory losses equate to greater than an estimated $2.58 billion.

Roadway segments and railroad tracks may experience damage due to ground failure and regional transportation and distribution of these materials will be interrupted as a result of an earthquake event. Losses to the community that result from damages to lifelines can be much greater than the cost of repair (HAZUS-MH 2.1 Earthquake User Manual, 2012).

Earthquake events can significantly impact road bridges. These are important because they often provide the only access to certain neighborhoods. Since softer soils can generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable. A key factor in the degree of vulnerability will be the age of the facility or infrastructure, which will help indicate to which standards the facility was built. HAZUS-MH estimates the long-term economic impacts to the County for 15-years after the 2,500-year earthquake event. In terms of the transportation infrastructure, HAZUS-MH estimates $77.7 million in direct repair costs to bridges, highway, railways, bus, and airport facilities. There are no losses computed by HAZUS for business interruption due to transportation or utility lifeline losses.

HAZUS-MH 2.1 also estimates the volume of debris that may be generated as a result of an earthquake event to enable the study region to prepare and rapidly and efficiently manage debris removal and disposal. Debris estimates are divided into two categories: (1) reinforced concrete and steel that require special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers (HAZUS-MH Earthquake User's Manual).

For the 100-year MRP event, HAZUS-MH 2.1 estimates 126 tons of debris will be generated. For the 500-year MRP event, HAZUS-MH 2.1 estimates more than 31 thousand tons of debris will be generated. For the 2,500-year MRP event, HAZUS-MH 2.1 estimates greater than 400 thousand tons of debris will be generated. Table 5.4.3-21 summarizes the estimated debris generated as a result of these events by municipality.

Table 5.4.3-21. Estimated Debris Generated by the 500- and 2,500-year MRP Earthquake Events

Municipality	100-Year		500-Year		2,500-Year	
	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/ Wood (tons)	Concrete/ Steel (tons)
Town of Boonton	0	0	182	51	1,798	920
Township of Boonton	0	0	266	91	2,752	1,784
Borough of Butler	0	0	208	63	2,133	1,220
Chatham Borough	0	0	342	103	3,432	2,161
Chatham Township	28	5	1,002	286	9,683	5,727
Chester Borough	0	0	101	34	961	640
Chester Township	0	0	322	79	3,120	1,427
Denville Township	0	0	618	187	6,249	3,646
Town of Dover	0	0	663	290	6,057	5,760
Township of East Hanover	0	0	1,383	617	13,943	13,647
Borough of Florham Park	0	0	1,034	414	10,201	8,928
Township of Hanover	0	0	1,386	599	13,700	12,624
Township of Harding	0	0	210	52	2,218	1,004
Township of Jefferson	0	0	377	81	3,714	1,405
Borough of Kinnelon	0	0	284	56	2,941	1,041
Borough of Lincoln Park	25	6	773	328	8,569	7,421

Table 5.4.3-21. Estimated Debris Generated by the 500- and 2,500-year MRP Earthquake Events

Municipality	100-Year		500-Year		2,500-Year	
	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/ Wood (tons)	Concrete/ Steel (tons)
Township of Long Hill	0	0	476	152	4,723	3,216
Borough of Madison	0	0	799	251	7,754	5,344
Borough of Mendham	0	0	181	46	1,825	865
Township of Mendham	0	0	241	52	2,441	948
Township of Mine Hill	0	0	103	31	990	564
Township of Montville	0	0	450	120	4,640	1,968
Borough of Morris Plains	0	0	267	96	2,746	1,946
Township of Morris	0	0	1,140	404	11,418	8,367
Town of Morristown	0	0	791	299	7,660	6,500
Borough of Mount Arlington	0	0	146	36	1,376	643
Township of Mount Olive	0	0	1,061	400	9,447	7,098
Borough of Mountain Lakes	0	0	159	40	1,607	756
Netcong Borough	0	0	98	36	915	649
Township of Parsippany-Troy Hills	0	0	2,559	1,008	25,881	21,872
Township of Pequannock	49	13	1,743	762	19,255	18,246
Township of Randolph	0	0	925	289	9,115	5,460
Borough of Riverdale	0	0	71	21	704	310
Borough of Rockaway	0	0	447	178	4,204	3,783
Township of Rockaway	0	0	633	193	6,338	3,472
Township of Roxbury	0	0	1,186	402	10,788	7,867
Borough of Victory Gardens	0	0	26	8	246	153
Township of Washington	0	0	566	155	5,370	2,709
Borough of Wharton	0	0	236	103	2,248	1,912
Morris County (Total)	**102**	**24**	**23,455**	**8,415**	**233,161**	**174,000**

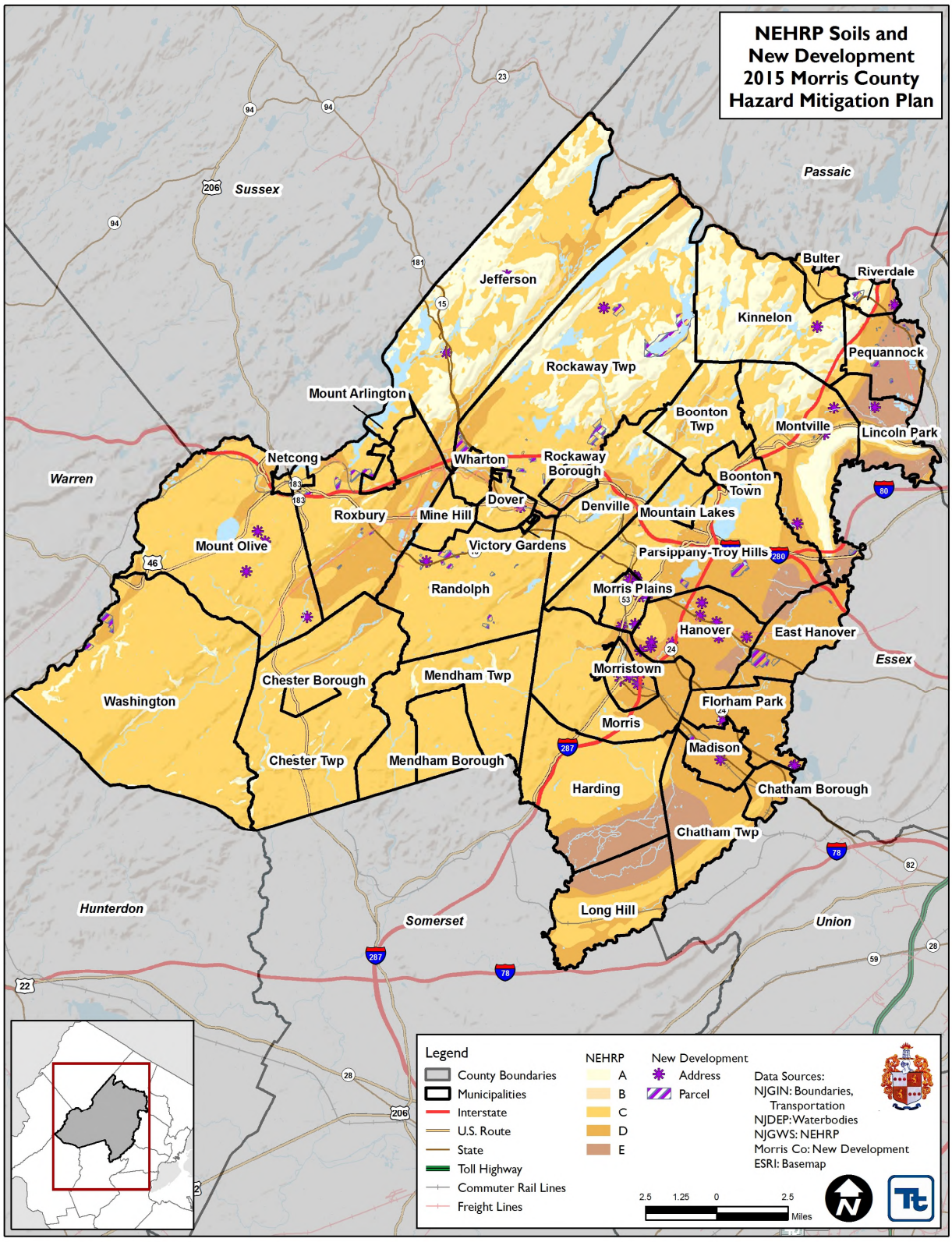
Source: HAZUS-MH 2.1

Future Growth and Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the County. It is anticipated that the human exposure and vulnerability to earthquake impacts in newly developed areas will be similar to those that currently exist within the County. Current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts than older, existing construction that may have been built to lower construction standards.

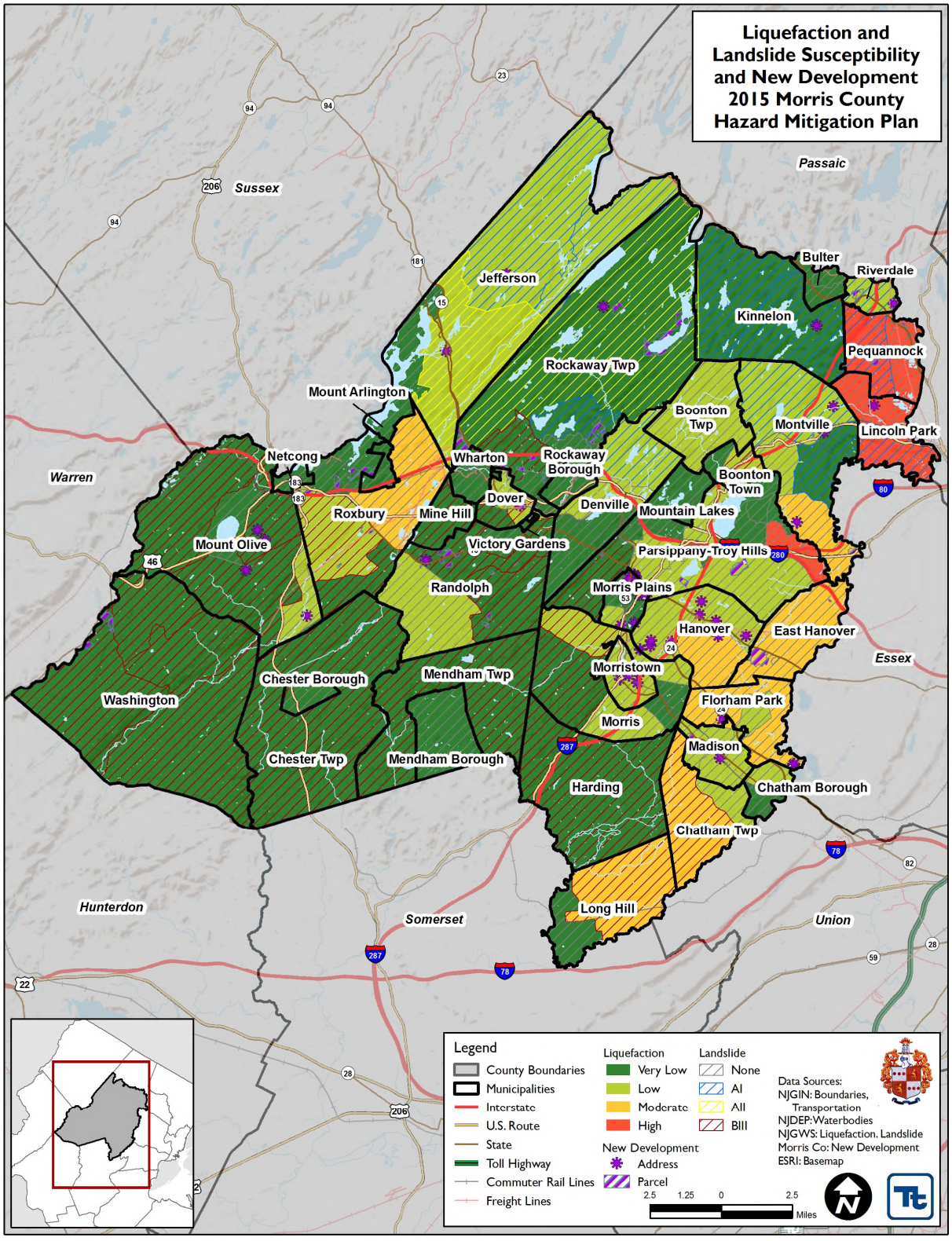
New development located in areas with softer NEHRP soil classes, liquefaction and landslide-susceptible areas may be more vulnerable to the earthquake hazard. Refer to Section 4, and Volume II Section 9 for potential new development in Morris County. Figures 5.4.3-9 through 5.4.3-10 illustrate the potential new development and NEHRP soils, liquefaction and landslide-susceptible areas across the County

Figure 5.4.3-9. Potential New Development in Morris County and NEHRP Soil Types



Source: NJGWS 2013, Morris County

Figure 5.4.3-10. Potential New Development in Morris County, Liquefaction and Landslide Susceptible Areas



Source: NJGWS 2013, Morris County

Change of Vulnerability

Morris County continues to be vulnerable to the earthquake hazard. However, there are differences between the potential loss estimates between this plan update to the results in the original 2010 HMP. For the 2015 update, probabilistic scenarios were evaluated using a Level 2 HAZUS-MH analysis. In addition, a more current and accurate building stock inventory was used for this HMP update.

Effect of Climate Change on Vulnerability

Providing projections of future climate change for a specific region is challenging. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the Earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes.

Secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity because of the increased saturation. Dams storing increased volumes of water from changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

Additional Data and Next Steps

A Level 2 HAZUS-MH earthquake analysis was conducted for Morris County using the default model data, with the exception of the updated building and critical facility inventories which included user-defined data, NEHRP soil data, as well as liquefaction and landslide susceptibility data. Additional data needed to further refine and enhance the County's vulnerability assessment include identifying un-reinforced masonry critical facilities and privately-owned buildings (i.e., residences) using local knowledge and/or pictometry/orthophotos. These buildings may not withstand earthquakes of certain magnitudes and plans to provide emergency response/recovery efforts for these properties can be set in place. Further mitigation actions include training of County and municipal personnel to provide post-hazard event rapid visual damage assessments, increase of County and local debris management and logistic capabilities, and revised regulations to prevent additional construction of non-reinforced masonry buildings.